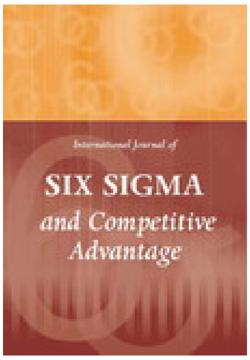

International Journal of Six Sigma and Competitive Advantage

ISSN online: 1479-2753 - ISSN print: 1479-2494
https://www.inderscience.com/ijssca

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DOI: 10.1504/IJSSCA.2022.10047023

Article History:

Received:	09 September 2021
Accepted:	07 February 2022
Published online:	17 April 2023

PMDECS approach of red bin analysis – the art of problem solving in manufacturing industry

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Abstract: Over the years, problem solving in manufacturing industries has become one of the key attributes and a differentiator in this competitive market. A notable fact, which has emerged from the literature of problem solving, is that most of the time it has been a reactive approach. If the approach has to be preventive then there must be automation or application approaches involving statistics. In developing countries where component manufacturers still struggle to implement an effective problem solving methodology, OEM's have relatively better awareness of problem solving but they are yet to have an effective problem-solving methodology, which can be cost effective, time saving and simultaneously have a preventive approach rather than a reactive approach. In this paper, authors have demonstrated PMDECS approach of red bin analysis, which reduces the issues and problems at source as a preventive approach. This is an alternative approach towards problem solving based on the Deming's PDCA cycle.

Keywords: red bin analysis; problem solving process; manufacturing problems; defects and defectives; supplier upgradations; supplier management; operation excellence; business process improvement; continual improvement.

Reference to this paper should be made as follows: Shandilya, S., Arora, J. and Vinayak, K. (2023) 'PMDECS approach of red bin analysis – the art of problem solving in manufacturing industry', *Int. J. Six Sigma and Competitive Advantage*, Vol. 14, No. 3, pp.300–329.

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1 Introduction

In this era of competition, the problem-solving ability of an organisation is the key to their success. Problem-solving is an essential activity, process, or a criterion for any entity or corporate which enables an environment for developing their competitive strategies (Liu and Ke, 2007). Today, the quality of a product or service has become a differentiating phenomenon and is specifically, it has evolved as a baseline for competition (Hellsten and Klefsjo, 2006). If any organisation wants to gain this competitive advantage, then quick and explicit problem solving is the key (Park et al., 1998). Over the years there have been many methods and approaches to do quality problem-solving in manufacturing industries. These have been around us from so many years still they have not been integrated with the routine problem-solving practices in the industry (Bamford and Greatbanks, 2005). To understand the problem-solving methodologies, one needs to get into the understanding of the 'process', 'methodology' and 'tools and techniques' as these are important dimensions for adopting a correct strategy for the organisation (Bamford and Greatbanks, 2005). Process has many definitions and out of all, the definition by oxford dictionary (Chalker and Weiner, 1998) which is, an activity that converts input into output by the means of using resources has been preferred by the authors. Tools and techniques can be defined as skills or methods used fulfill a definite task (McQuater et al., 1996) and methodology is a defined as a system of actions that are used in specific area to obtain a desired result (Chalker and Weiner, 1998). There are various methodologies, tools and techniques which are used in the process to achieve results for example: tools can be classified into histogram, pareto chart, why-why analysis, flowcharts etc. whereas techniques are statistical process control, failure mode effect analysis, design of experiments, quality function deployment etc. and on the other hand methodologies can be named as Six Sigma, TQM, Quality Circle approach etc. (McQuater et al., 1996).

2 Literature review

One of the most common methodologies adopted for establishing quality practices and problem solving is TQM - Total Quality Management. There are various factors like quality planning, customer satisfaction, process management etc. around which TQM has been established and this methodology has various tools and techniques (Tarí and Sabater, 2004). This method emphasises on the importance of a systematic management of process and design based on cross-functional approach (Cua et al., 2001). The literature also suggests that TQM is aligned with the 7 principles of Malcolm Baldrige business excellence model (Sila, 2018). Six Sigma also has been popularised from more than last 2 decades, especially in late nineties, it has spread like anything in industries (Goh, 2002). It is a methodology through which an industry reduces or eliminates their defects and achieve reduction in variation (Kaushik and Kumar, 2017). According to the author 'Ronald D. Snee', for improvement through six sigma ultimate goal is to achieve "process excellence" (Snee, 2010). Six Sigma as a methodology which uses Define, measure, analyse, improve and control as the steps to problem solving (Linderman et al., 2003). Quality Circle is another methodology that eliminates problems by enhancing total employee involvement within the organisation (Everett, 1991). This methodology involves a group activity where employees from specific functions form a group and meet at regular intervals to solve a particular problem (Thirugnanam et al., 2007). If participation in quality circles is ensured then this methodology enhances learning and updating of skills of employees further reducing issues at the workplace (Marks et al., 1986). On the other hand, the methodology based on the principles of Lean manufacturing includes various problem solving tools and techniques like Just in time, manufacturing layout, supplier management etc. in an integrated way (Shah and Ward, 2002). The objective of this method is reduce eliminate waste, irregularity and strenuous conditions at the work place (Womack et al., 1990). The literal meaning of the word lean manufacturing is manufacturing without waste (Taj, 2008). According to author Shahram Taj, despite knowing the concept of being waste free, still majority of the organisations they do not adhere to the practices of Lean (Taj, 2008).

If we have to research about problem solving tools and techniques then the world of literature is full of such tools like Six Sigma or DMAIC, 5W1H, 8D or PDCA. Six Sigma is business process and performance improvement philosophy and methodology , which statistically targets to reduce the issues in terms of defects and abnormalities to almost 3.4 defects per million opportunities (Desai et al., 2008). Over the years, Six Sigma has been used by majority of the organisations and industries as a methodology for improvement (S.Shandilya, 2016). Moreover, it has assisted professionals and various organisations in resolution of their problems and issues where the root cause analysis was not as easy as solutions were not known and also it required different subject matter experts (Breyfogle, 2003). Six Sigma is also known as DMAIC because its entire methodology is categorised in phases of Define, Measure, Analyse, Improve and Control. Still, there are considerable limitations of this methodology that restricts its application and usage in some industries (Antony, 2004). As per the paper of Prof. Antony Jiju in 2004, Six Sigma methodology has following limitations but are not limited to:

- Availability of refined and structured quality data within the processes.
- The countermeasures and solutions offered by the six-sigma project may be expensive and time taking.

- The selection of a Six Sigma project is also very judgemental and subjective. It is mostly based on customer defects. So, this may not cover those problems which are generated within the processes until and unless the problem is not reported by the customer or next process.
- The CTQ's or Critical to Quality characteristics can never be a constant. These characteristics may change and differ from product to product and time to time. Therefore, these must be optimised and examined all the time (Goh, 2002).
- The six-sigma project cost can be a significant investment for an organisation and many organisations under small and micro categories may not be able to afford such expertise.

Similarly, other techniques such as plan do check act (PDCA) also forms the base of a structured problem solving (Liang and Zhang, 2010) but the PDCA also known as Deming's wheel or Deming's circle does not talks or mentions about the control of the process or the solution. This would definitely lead to towards maintenance of the quality but not the improvement of quality. Moreover, if this would not help us in improving the quality then we would be left with the only way and that is to improve the product design just to maintain the quality (Shingo, 1986). These tools and techniques may be effective for problem solving. Several research and studies have proved it but there has been no such methodology which in general focusses about identification of problems and defects at the source. As per the book of Shigeo Shingo in 1986, he also mentioned that quality can never be controlled through inspection and thus have mentioned about the Poka-Yoke system to prevent the occurrence of defect at the source (Shingo, 1986). Poka-Yoke can prevent the defect even at the source but for the structured elimination of the defects, we must have problem solving methodology that would help in identifying the cause of defects at the source and eliminate them forever.

One of the most widely used methodology especially in Japan and sub-continent is Quality Circle or QC Circles. Quality Circles are considered a significant option which are aimed to help the employees to achieve greater job satisfaction which in turn seeks to increase productivity, efficacy and quality through direct satisfied employee participation. With industrial blue-collar workers, most Quality Circle advances have occurred. Quality Circles may, however, be established with success anywhere there are groups of individuals, in or out of the industry. It does not matter whether the development of a Quality Circle is part of long - term or short planning, the rules remain the same and the principle remains unchanged (Barlow, 2011). Many workers have the potential to manage problems in an organisation. In a conceivable and imaginative way, they approach and solve the broader spectrum of challenges at work. This theory suggests that people still have a brain, and it is important to give them the chance to use their thinking capabilities in a positive way (Koneru, 2018). It has been proposed that there should be differences between the purposes of 'in-process' and 'end-product.' End-product targets are macroscopic and deal with cost savings, improved efficiency, improved productivity, work attitudes, and security. Thus, the end-product targets analyse the effect of the operation of QC on the performance of the whole enterprise. Many recent studies have investigated the end-product objectives of QC (Tang et al., 1987). Evaluations of the effects of these organisational measures have been constrained by two limitations:

1 the degree to which the outcomes can be attributed to the intervention

2 the presence of a positive-findings tendency (Woodman and Wayne, 1985).

Quality circles (QCs) have long been observed among the most promising methods to improving the productivity of American workers. About 90% of the Fortune 500 firms are now projected to have QC systems. A QC is a group of employees within the same field of work who interact regularly on a voluntary basis to define, discuss and solve different work-related problems (Lawler and Mohrmahn, 1985). There are other tools and approaches also, like statistical process control (SPC), which is also found valuable to make real time decisions and gain improvement but it requires the statistical know-how for operators and supervisors (Elg et al., 2008).

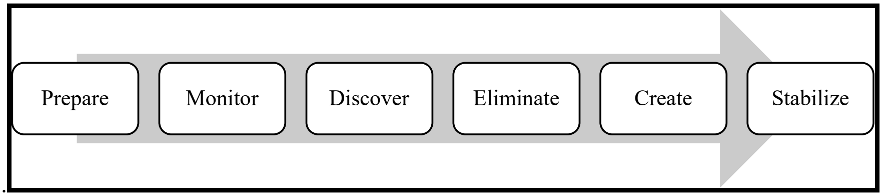
All the above-mentioned problem-solving methodologies are proven and have resulted into significant result for these industries but have their own limitations which are already mentioned. Now, considering those limitations still there is a lot of scope in the area of problem-solving, the author's devised an alternative approach which can eliminate the problem in the industry. This approach is named as PMDECS approach of red bin analysis. The term red bin not new and it is being used in the industry. Red bin is like a normal bin or a basket which is aesthetically red in colour and appearance. It is used to keep all the in-process rejection of the assemblies/sub-assemblies/child parts separately so that it can-not gets mixed with the regular conforming parts or components which are generally placed in a green colour bin. Its colour is deliberately kept as Red to alert and notify the shop floor employees (operators, supervisors and inspectors) to make them aware that a defect has been generated. To focus on the problems at the Red-bin stage i.e. To analyse and solve the problems or issues or defects that generate at the sub-assembly process so as to scale down the overall defect generation process at the customer or the OEM and thus overall improve the problem-solving process and the efficiency of the organisation. This analysis is done on a proactive basis, before the assembly or manufacturing of the complete final product. The child-parts or subcomponents are itself focused for elimination of problems so that even a small error in them should not lead to a defective assembly or the product which would further increase cost of analysis and problem solving.

3 PMDECS approach of red bin analysis

The authors have designed the PMDECS approach of Red-Bin Analysis by the adoption of the framework of Deming's PDCA cycle and the Japanese quality circle methodology. The intent is to evolve PMDECS approach of red bin analysis as a structured and integrated problem-solving process that encompasses all the conventional problem-solving tools earlier used by the industries.

The approach has been framed to be implemented in six phases, namely Prepare, Monitor, discover, eliminate, create and stabilise (PMDECS). These six phases help one team to effectively and systematically solve the problems. These structured 6 phases have specific tools, intent and methodology to find and eradicate the causes of problem and eliminate the effect of the problem. One by one let us define these 6 phases.

Figure 1 Red bin analysis – the PMDECS approach



3.1 Prepare

The first and one of the most important phases of red bin analysis is this prepare phase. In this phase, the team building, resources, infrastructure, intention of analysis, benefits, objective, cost metrics and customer issues are set, planned, analysed and used for further attempt towards problem solving. The better this phase is planned and implemented, more will be the level of result and problem solving. Let us try to understand this phase step by step which will further be illustrated with the help of a case study project in this paper.

a Build a team for daily monitoring (it can also be hourly or shift wise based on the production plan and rate) of in-process parameters, sub-assembly parts and sub-components.

- This team shall be provided with a data recording template for processes and products.
- This team shall be competent enough to understand the process, products and their non-conformance with respect to their specific domains or area.
- This team shall comprise of routine inspectors, operators or supervisors.
- There is no specific requirement of level of professional education attained by team though it is preferred that at-least one or few of the team members must know how to read and write and also to understand the customer requirements.
- There must be a facilitator to the team who shall be accountable for the activities within the 6 phases and shall be responsible for managing the resources for the team and project.

b Resources and Infrastructure shall be allocated to the team. Here, resources are mainly the red bins which shall be placed within every stage of the very process before final inspection. Apart from the red-bins, a specific location shall be defined where the red-bins will be placed during the process and a special place where the red-bin shall be analysed after the process.

c A place shall be dedicated for daily morning meeting of the team at shopfloor. That place shall be equipped with registers, writing boards and pin-boards etc. to gather, monitor and analyse the data.

d A formal approval of the management and continuous support from the middle management shall be ensured before starting any project related to Red-Bin Analysis. This sub-step is of utmost importance in Prepare phase as its perfect implementation will lead towards consistent focus, regular review and constant involvement of people within the organisation.

Red-bin analysis projects are not very cost incurring like a conventional Six Sigma project as there is no need to train people on advance statistics and certain other technical tools but still, these projects would require consistency and genuine effort of the employees and that shall not be achieved until and unless the management is committed for the improvement.

3.2 Monitor

The second phase is the key phase in red bin analysis. In this phase the regular red bin meetings are conducted in a definite time slot to discuss the ongoing process and product rejections, abnormalities and defects. This phase is conducted in minimum two stages, which are differentiated based on the time duration and intervals of meeting.

a The first stage is where every day the meetings are conducted in routine and daily occurring issues and defects are discussed. Correction and Corrective actions are planned at the time itself and further, a plan is made to achieve the customer target without any significant disruptions.

b In the second stage, a meeting is conducted weekly, fortnightly or monthly to discuss the two things:

- That issue which has been occurring in large numbers or quantity that has impacted the customer schedule, delivery in a particular shift or day.
- That issue which has been re-occurring daily or repeatedly despite not being among those issues which were highest in number or quantity (*as explained in the point above*)

This phase of PMDECS approach (red bin analysis) is depended on the data collection which has to be monitored. The data can be collected manually or through automated systems but it needs to be there. The data shall comprise of process parameters, product specifications (as per the customer requirements, criticality and regulatory bodies). This data should be collected within process, at the sub-stations and also at all the inspection stages.

Notes: PMDECS approach of red bin analysis do not promote to increase the inspection stages or to do repeated inspections but it recommends to have sufficient inspection stages initially for capturing the data. Once the data verifies that there is no need of furthermore inspection, then the inspection and data collection stages can be diluted based on fewer samples or less sample size lots or even the stage can be eliminated based on the need and requirements.

Based on the data captured, the accountable teams shall ensure its regular monitoring during the red bin meetings at multiple stages as explained above.

3.3 Discover

In the discover phase of red bin analysis, the emphasis is on finding the actual problem. In this phase, the team needs to action as per the data monitored above though this phase is largely to plan the action but there would some actionable points which needs to be done immediately. This action shall describe two major deliverables of the projects which further shall be based on two major discoveries:

3.3.1 Discover the problem

With the help of the data monitored in the multiple stages in the Monitor phase, the team shall find out those issues which are continuous and simultaneously larger in number. Those issues can be related to process or product but shall follow the principle of recurrence and quantity. Only recurrence is not sufficient and neither focusing on quantity would also not suffice. Moreover, these issues then should be linked to the respective characteristics of the process or product based on the existing control plan, PFMEA or direct customer requirements.

3.3.2 Discover the solution

Based on the above discovery and its finalisation, the team needs to identify the following solutions:

- troubleshooting methodology and reaction plan
- correction
- corrective action
- preventive action
- horizontal deployment.

Notes: The beauty of red bin analysis is that it never restricts you to the use of a particular tool or a typical technique. It rather recommends you to use any tool that is specific to the problem. It doesn't matter if it is SPC or 7QC Tools, Brainstorming or Pareto chart or Why-Why Analysis, the user has all the freedom to use his and their teammate's knowledge to find-out the solutions. In the case-study demonstrated later in this paper, the authors have used the tools specific to the problem found in that industry. This does not mean that all red bin practitioners have to follow the similar tools. Red bin analysis is a structured approach that leads towards a systematic problem solving. Still, there are certain tools which have been recommended by the authors later in this paper for the young problem solvers and beginners in this area.

In red-bin analysis, focus shall be given on finding out the cause at first and ultimately the root cause through a series of intermediate causes which are mentioned below:

- Finding out the probable causes: a study to find out the preliminary causes.
- Highlighting causes: a study to funnel out the preliminary causes and factoring the impactful causes.
- Extracting the main cause: validating the potential cause to leave behind the invalid causes.
- Digging out the root cause: finding out the root of every main cause.

Theses causes can be found out through a structured approach as mentioned in Table 1. It is a systematic and investigative process to find out the root cause of the problem, which involves series of activities to be done with the team.

Table 1 Discover Phase - Steps to find Root cause of a problem

Activity number	*Activity*	*Outcome*
1	Brainstorming	Probable Cause
2	ABC analysis or nominal ranking technique	Potential Cause
3	Validation	Main Cause
4	Why-why analysis	Root cause

3.4 Eliminate

In this phase, the focus of the team is on implementation of all the solutions that were found out in the Discover phase. These solutions should lead towards reduction and ultimately elimination of the problems, issues or abnormalities that were found out at the start of the red bin project.

- A structured plan of implementation of each type of actions related to troubleshooting, correction, prevention and sustenance shall be planned and adhered.
- The adherence or implementation of these plans shall be monitored, supervised and documented.
- For any action which requires a significant change should have a prior approval of the management and intimation to the customer.

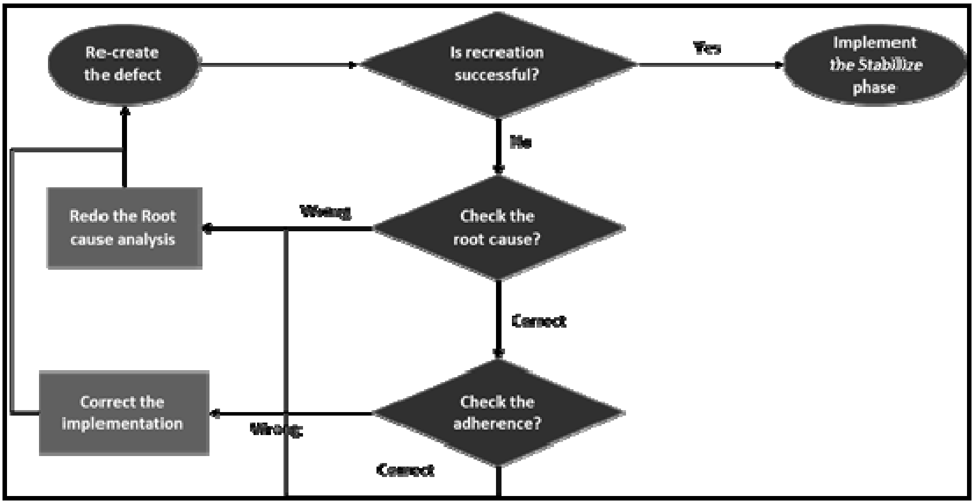
3.5 Create

This is a very unique phase of PMDECS approach of red-bin analysis, where a typical activity shall be carried out to verify, validate and ensure the effectiveness and impact of the solutions implemented. This phase shall only be done once the defined actions have been implemented and the organisation have sufficient inventories to cater the immediate need of the customer. In this phase, the team shall be re-creating the issues, defects or the problem in a systematic manner by re-introducing the errors, problems that were found out during the discovery phase. It can be done through any method like simulation or experimentation, but this phase will ensure that correct solution to the problem has been found out or not.

The required steps to execute this phase are:

- Select the process/product on which this red bin project is conducted.
- Select the shift or day in which this activity shall be conducted.
- Select the quantity of product which shall be re-created as the defect as per the cycle-time of the process and the takt-time.
- Re-create the defect.
- Remove the defect.
- Do it for sufficient samples to ensure the validation of the root cause.

Figure 2 Flowchart of actions to simulate or recreate the defect



After the activity, the team shall have following possibilities (Figure 2).

1 The re-creation and elimination of the defect was successful. In this case proceed to the next phase.

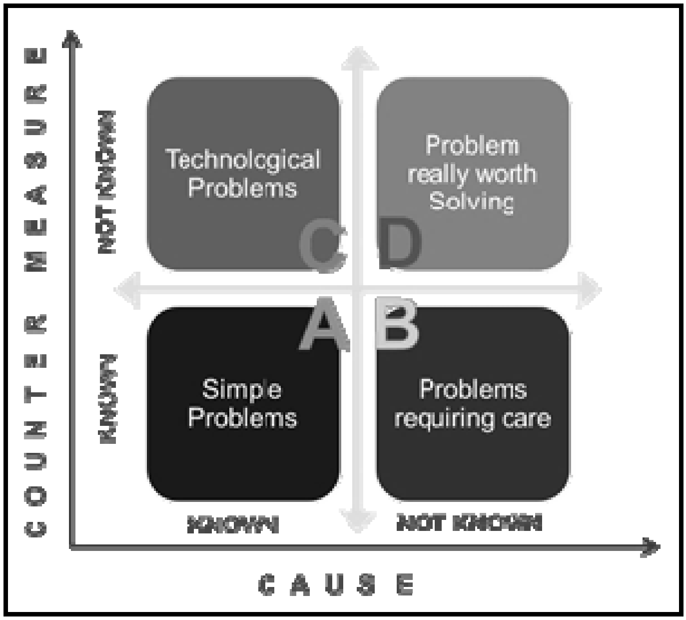
2 The re-creation and elimination of the defect was un-successful. This means that the obtained root-cause is not an actual root cause due to which the problem occurred. The obtained cause can also be another affecting cause to the problem but definitely it is not the root cause. Then again, the team needs to go through the list of probables, potential and main causes and further need to analyse the correct root cause and repeat the process.

3.6 Stabilise

The final phase in the journey of Red-Bin analysis. In this phase, the emphasis of the team is to ensure the results out of the project and further to do the effectiveness monitoring. The team shall be ensuring the required results are met as planned. They need to communicate the entire process and results to the management and stake holders. Further, all the process shall be documented and a summary shall be prepared in a template. Also, the team shall be rewarded as per the organisation's policy and kept motivated to continue the journey of improvement and problem solving.

The team should create a permanent problem bank which shall be a list of problems that have been a part of the organisation (even for a smaller duration). These problems shall be described based on their causes, solved or not and all the actions which have been taken to eliminate them shall be updated. This problem bank will be acting as a history and a reference guide for all the future problems. Further, the problems shall be classified based on the organisation's knowledge on its countermeasure and related causes (Figure 3).

Figure 3 Categories of problem



4 Research method

As a researcher and practicing consultants, authors were handed over an assignment of process improvement at one of the suppliers of a two-wheeler manufacturing giant. They were approached by their CEO in a formal meeting wherein the organisation was worried about their increasing customer complaints and subsequent in-house defects. M/S Nidhi Metals is a sheet metal manufacturing organisation who caters to a number of two-wheeler, four-wheeler and other automobile original equipment manufacturers (OEMs). Their processes were largely welding, machining and press-operations. In the meeting, their CEO focused on the increasing complaints. While discussing and counter-questioning, authors found out that Nidhi metals was suffering from customer complaints for more than 2 years, but the numbers weren't too high to cause a worry. Now, in past 6-10 months, with the increasing number in defect PPM, the organisation was worried with respect to their future prospects and business.

The authors decided to implement the Six Sigma methodology but after the review of the entire team, they found that the team at the organisation is not well acquainted with the Six Sigma methodology. Moreover, considering the limitations of Six Sigma approach (as mentioned in the literature review), the authors also decided to go for a different methodology that would focus on the defects at source and which may not need statisticians and advanced level problem solvers as the organisation belongs to a small and micro category of organisation. The authors started with the GEMBA at shop-floor and did repeated visits, talked with shop-floor operators, supervisors and finally decided to go-ahead with a different approach for killing the problem. In the following paper, the authors have demonstrated the methodology and explained how the use of PMDECS approach of red bin analysis came to the rescue of M/S Nidhi Metals.

4.1 The case study on M/S Nidhi Metals Pvt. Ltd.

4.1.1 Information about the Industry

- ✓ Name: M/S Nidhi Metals Pvt. Ltd.
- ✓ Chairman: Mr. B.S. Shekhawat
- ✓ Managing Director: Mr. Jayant Shekhawat
- ✓ Sector: Automotive Industry
- ✓ Category: MSME
- ✓ Manufacturing type: Mass production (welding assembly and machining)
- ✓ System certification: ISO 9001:2015, ISO 14001:2015, IATF 16949:2016
- ✓ Revenue: 2017–2018 – INR 150 Crore

4.1.2 Understanding and assessment of the organisation

M/S Nidhi Metals is an automotive supply chain partner to few automobile industries (in two-wheeler, four-wheeler and commercial vehicle sector). They were having quite a few in-house rejections through their manufacturing processes. The real problem started when they received a call from two of their customers regarding a customer complaint and which was similar in nature. The problem got repeated over the months and now they got an official quality complaint letter from the customers. This is where, we (the authors) chipped in. The managing director of Nidhi metals wrote to the authors, regarding the consultation of their organisation. The authors visited the premises of the company and had a meeting wherein they understood the problem of the owners. The owner directly asked us to perform six sigma projects so that they can get rid of the customer complaints. The authors conducted the Gemba and found that already the organisation implemented a rigorous inspection method (all manually done), they were performing statistical studies like SPC on their assembly process for critical to quality dimensions. Before finalisation of the contract, the authors convinced the management of Nidhi metals to not insist on the six-sigma project. Let them have the free hand to choose the methodology which shall be the best fit with respect to the core and real problem of the organisation.

Upon finalisation of the contract, the authors did an initial but detailed shop-floor visit of the entire organisation to understand the system, people and their working. Following are some general details of the organisation that the authors noted down during their initial assessment:

1 Size of the organisation: 140 + employees (white + blue collar)

2 Education background: 12th pass – 15 employees (blue collar)

- ITI Certificate – 35 employees (Blue collar)
- Diploma holder – 80 employees (Blue + white collar)
- Engineering graduate – 4 employees (white collar)
- Non-engineering graduate – 9 employees (white collar)
- Postgraduate and above – 1 employee (white collar)

3 Welding assembly line: 05 nos.

4 Rework stations: 08 nos.

5 Inspection stages: 05 nos. (at the end of each line)

Additionally, pre dispatch inspection is also done every time before any dispatch

6 Working hours: 09:00 AM to 06:00 PM (General shift)

06:00 AM to 02:00 PM (A-shift)

02:00 PM to 10:00 PM (B-shift)

06 days working

All white-collar professionals they come in general shift

7 Each production line has an in-charge who is called as the supervisor of the line and is a diploma holder by qualification.

8 Every shift has a quality, production, maintenance and store supervisor and among them production supervisor is the overall in-charge

9 Overall, 5S of the organisation was in good condition and have achieved a score of 82% during our initial 5S audit

10 Quality tools and technique knowledge among the employees

We conducted an overall organisational assessment of quality tools through the following 3 stages:

- Stage-1: All production shop-floor employees along with people from quality and maintenance
- Stage-2: All supervisors within the organisation.
- Stage-3: Management person and staff.

a 7 QC tools

- More than 80% of the organisation know about this.
- Less than 10% of the organisation knew its application.

b Corrective and preventive action

- More than 95% in the organisation knew about this.
- More than 60% knew about the corrective action.
- Less than 15% knew about the preventive action.

c Quality circle

- Less than 40% knew about this approach.
- Less than 3% have the implementation experience.

d Six sigma

- Less than 1% knew about this.

e SPC tools and techniques

- Less than 10% were aware about this.
- Less than 1% have the know-how of the application.

After the above assessment, the authors realised that implementing the six-sigma project can be quite strenuous as compared to the other industries as people doing the job here have almost no knowledge of the six-sigma concept and statistical tools. Even after training them, what about when the contract with the authors is over, how the improvement shall be sustained and further problem would be avoided? These were certain questions which were in the mind of the authors. They decided to have structured GEMBA of the core manufacturing process.

During the GEMBA, the authors observed certain significant actions and events happening at the child part, subcomponent welding stages. There was a lot of reworks happening on-station during the welding of the child part components and sub-assemblies. Many of those parts were actually fed to the final assembly line. As the final assembly line has nothing to do with affected child part dimension, they never checked it and thus it tends to get escaped from the final inspection also. Immediately, inspection of the child parts was also started and the detection of some problems began to surface. This immediate action has actually stopped the customer complaint but this was not the bigger issue. The major issue was the culture of problem solving wherein unless the issue or problem is being reported from the higher authorities or the customer, the people never try to prevent it. The authors decided to implement a 'red bin analysis' methodology which can help them in preventing the occurrence of such problems so that they may never lead to customer complaints and simultaneously rework is also eliminated.

4.2 Phase 1

4.2.1 Prepare

A team was formed for this activity and the managing director of the organisation took his personal interest in this project and he himself became the champion of the project. He advised the quality supervisor to help the authors in the team formation. Finally, after the assessment of each assembly line, the authors selected a team of 4 members from the line having the greatest number of defects and defectives.

- The project champion ensured that the Red Bins are available at all the manufacturing stations, with a lock-key system so that no one can remove the defective parts without anyone's information and the quality supervisor is keeping a check on routine activities of the project.
- He also ensured that there is a designated place for the Red-bins, daily morning meeting, meeting board and the required registers.
- Since, the project champion is the part of the management, he also issued a formal letter and a notice in the organisation regarding the project. He ensured that there is a full support given to the project team members and the consultants.

4.3 Phase-2

4.3.1 Monitor

In this phase, the monthly meeting plan and the daily activity plan was made. This activity plan describes the activities to be done on daily basis (Table 2) and the monthly meeting plan describes the meeting frequency. In the following table the plans have been illustrated.

Table 2 Daily activity plan

Daily red-bin (RB) activity plan sheet										
Activity	*9:00 AM*	*10:00 AM*	*11:00 AM*	*12:00 PM*	*1:00 PM*	*2:00 PM*	*3:00 PM*	*4:00 PM*	*5:00 PM*	*6:00 PM*
RB Board updating										
RB meeting										
RB data collection										
RB defects counting										
RB material shifting										

Table 3 Daily defect monitoring sheet

Daily defect monitoring sheet – half day										
Defects	*9:00 AM*		*10:00 AM*		*11:00 AM*		*12:00 PM*		*1:00 PM*	
	Parts	*Defects*	*Parts*	*Defects*	*Parts*	*Defects*	*Parts*	*Defects*	*Parts*	*Defects*
Weld undercut	88	56	97	48	95	47	101	34	93	62
Zig-zag welding	88	17	97	22	95	19	101	20	93	29
Blow hole	88	17	97	14	95	16	101	7	93	25
Spatter	88	66	97	62	95	64	101	69	93	68
Uneven weld	88	6	97	9	95	12	101	16	93	11
Puncture	88	3	97	7	95	9	101	14	93	11
Excess Weld	88	11	97	9	95	9	101	7	93	11
MIG wire fault	88	4	97	7	95	9	101	2	93	8
Weld miss	88	12	97	6	95	7	101	6	93	15
Weld incomplete	88	3	97	1	95	2	101	4	93	1
Stopper offset	88	1	97	0	95	2	101	1	93	1
Tank pin shift	88	0	97	0	95	0	101	0	93	0
Cushion bolt shift	88	0	97	0	95	0	101	0	93	0
Total	88	196	97	185	95	196	101	180	93	242
Defect per Unit (DPU)	2.23	1.91	2.06	1.78	2.60					

Table 4 Daily defective (ppm) monitoring sheet

Daily red bin rejection PPM monitoring sheet													
Day	*9:00 AM*			*11:00 AM*			*2:00 PM*			*4:00 PM*			*Daily PPM*
	P	*R*	*PPM*	*P*	*R*	*PPM*	*P*	*R*	*PPM*	*P*	*R*	*PPM*	
1	178	92	516,854	196	66	336,735	164	110	670,732	188	73	388,298	469,697
2	184	76	413,043	193	65	336,788	191	100	523,560	186	101	543,011	453,581
3	172	57	331,395	160	57	356,250	191	56	293,194	177	50	282,486	314,286
4	166	63	379,518	170	80	470,588	206	90	436,893	186	59	317,204	401,099
5	171	96	561,404	199	90	452,261	188	90	478,723	172	63	366,279	464,384
6	173	73	421,965	201	86	427,861	169	55	325,444	192	52	270,833	361,905
7	175	82	468,571	163	65	398,773	201	86	427,861	155	72	464,516	439,481
P	Parts manufactured												
R	Parts rejected												

Table 5A DPU monitoring sheet (week 1 and 2)

DPU (defect wise) monitoring sheet																	
	Date																
Defects	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*W1*	*8*	*9*	*10*	*11*	*12*	*13*	*14*	*15*	*W2*
Blow hole	79	136	40	91	85	120	139	690	67	167	134	80	135	96	179	72	863
Cushion bolt shift	0	4	0	7	4	6	4	25	7	0	5	3	5	6	5	0	24
Excess Weld	47	19	76	37	71	88	21	359	70	55	25	37	71	35	93	22	338
MIG wire fault	30	48	41	38	37	24	47	265	32	29	24	37	38	37	43	48	256
Puncture	44	22	10	11	23	21	17	148	11	7	22	12	24	9	8	23	105
Spatter	329	211	131	123	105	251	66	1,216	103	114	227	289	164	60	40	106	1,000
Stopper offset	5	2	4	7	2	1	8	29	7	10	11	3	5	7	11	7	54
Tank pin shift	0	4	3	3	3	2	2	17	3	1	4	2	1	4	3	4	19
Uneven weld	54	61	57	70	30	15	31	318	67	13	48	6	43	26	77	29	242
Weld incomplete	11	25	33	25	27	9	20	150	14	17	18	5	7	24	29	26	126
Weld miss	46	22	57	52	95	83	84	439	69	90	70	51	57	35	13	76	392
Weld undercut	247	65	167	80	176	182	119	1,036	119	92	151	114	97	190	146	74	864
Zig-Zag welding	107	143	162	147	174	141	144	1,018	146	151	152	177	161	175	138	158	1,112

Table 5B DPU monitoring sheet (week 3 and 4)

DPU (defect wise) monitoring sheet																	
	Date																
Defects	*16*	*17*	*18*	*19*	*20*	*21*	*22*	*23*	*W3*	*24*	*25*	*26*	*27*	*28*	*29*	*30*	*W4*
Blow hole	104	57	140	42	47	168	28	75	557	80	29	144	115	52	163	95	678
Cushion bolt shift	4	4	1	5	1	5	0	0	16	0	6	5	7	2	6	6	32
Excess Weld	42	92	13	95	88	36	93	79	496	23	96	77	96	80	91	42	505
MIG wire fault	34	34	45	53	27	35	52	55	301	30	50	32	42	54	23	52	283
Puncture	13	18	9	24	15	8	21	20	115	19	12	8	17	13	10	8	87
Spatter	185	65	178	120	136	50	135	281	965	244	94	44	75	20	44	46	567
Stopper offset	6	11	6	3	12	3	11	11	57	12	3	1	2	3	8	11	40
Tank pin shift	3	0	1	1	1	4	2	4	13	2	2	0	4	2	1	0	11
Uneven weld	40	75	11	5	80	19	88	8	286	9	65	53	20	79	9	70	305
Weld incomplete	30	31	32	15	12	21	21	28	160	17	32	7	14	32	18	11	131
Weld miss	38	12	63	56	24	29	14	44	242	96	63	31	22	68	21	15	316
Weld undercut	68	183	118	79	194	102	157	155	988	204	61	150	166	193	195	147	1,116
Zig-Zag welding	177	149	140	134	157	164	152	133	1,029	162	160	131	151	142	143	159	1,048

Based on the schedule, shift wise data monitoring activity started at the defined intervals. The quality parameters like Defectives in PPM (parts per million), Defects in DPU (Defects per unit) were monitored and noted down (Tables 3 and 4).

Now based on the daily rejections (PPM and DPMO) recordings, a data sheet is prepared to note down the following:

1. top 3 defects of the day
2. top 3 defects of the week
3. top 3 defects of the month
4. consistent defects of the day
5. consistent defects of the week
6. consistent defects of the month

These defects are compiled on a data sheet Table 5(a) and Table 5(b) which has been formatted especially for such type of data collection. Moreover, a new method has been devised based on cause and effect matrix to further provide the weighted score (Table 6) to discover the top and consistent defects.

After the compilation of the above data, a weighted analysis was done to find out the top and consistent defects of the day, week and month. The defect which qualifies to be the topmost and simultaneously the consistent one is selected as the project for the month (Table 7). Rest other defects are being taken care through routine troubleshooting, existing corrective and preventive actions.

4.4 Phase 3

4.4.1 Discover

Based on the data collected in the monitor phase, in this phase we discover the top and consistent defects by using:

a Pareto diagram (for top defect of the month – Figure 4)

b Newly devised weighted score method (for consistent defect – Table 7)

Figure 4 Pareto chart for monthly defects (see online version for colours)

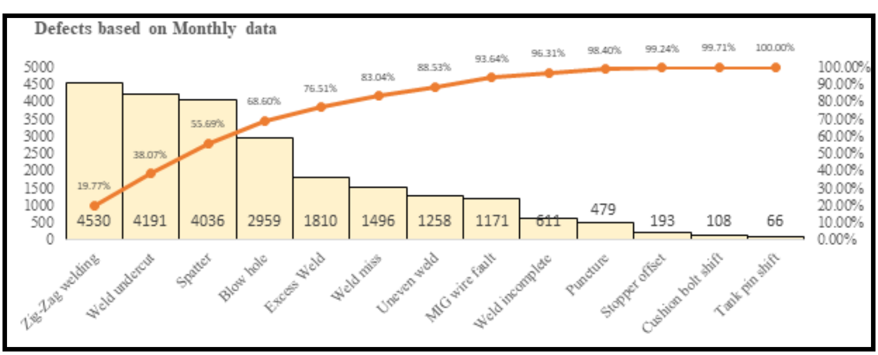


Table 6 Weighted score master table

Defect rank	*Score*		
	Daily	*Weekly*	*Monthly*
Top defect	3	6	9
Second	2	3	6
Third	1	1	3

The above pareto analysis clearly displays the top defect of the month and it also identifies the top contributing defects in the month but still, it is not clear that which are the consistent defects in the month. One important aspect to solve any problem is to identify the consistent defects. The top defect can be due to one or two days of special causes but it may not consistently trouble the operators and the team but those defects which consistently contribute to the rejection for the entire month are the ones causing some serious trouble. Our team devised a 'weighted score method' (Table 6) based on the already existing cause and effect matrix where we give the scores to the defects based on the daily, weekly and monthly occurrences. Following is the table defining the scores for the defects.

Now, based on Table 6, we provided the score to the defects which were recorded in the DPU (defect wise) Monitoring Sheet (as shown earlier). The overall idea is identifying the top and consistent defect to select for the project so that a detailed analysis can be done to eliminate it and mean while the other defects shall be taken care by the other teams and existing corrective and preventive actions.

Figure 5 Fishbone diagram (see online version for colours)

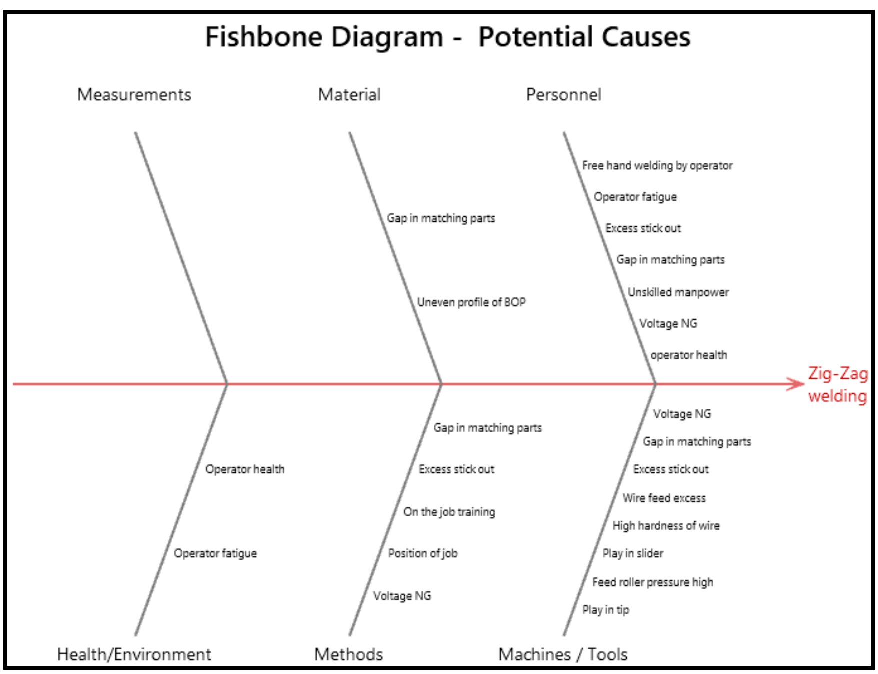


Table 7 Overall monthly weighted score of all the defects

Defects	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*W1*	*8*	*9*	*15*	*W2*	*16*	*17*	*28*	*29*	*30*	*W4*	*M*	*Score*
Zig-zag welding	1	2	2	3	2	1	3	1	3	2	3	6	2	2	2	1	3	3	9	85
Weld undercut	2	0	3	0	3	2	1	3	2	0	0	1	0	3	3	3	2	6	6	67
Spatter	3	3	1	2	1	3	0	6	1	1	2	3	3	0	0	0	0	0	3	56
Blow hole	0	1	0	1	0	0	2	0	0	3	0	0	1	0	0	2	1	1	0	24
Excess weld	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	5
Weld miss	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	1
Uneven weld	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Mig wire fault	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Weld incomplete	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Puncture	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Stopper offset	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Cushion bolt shift	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Tank pin shift	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Table 8 Potential causes obtained through nominal group technique

Nominal group technique										
S. no.	*Probable causes*	*Jayant*	*Ramavtaar*	*Hari*	*Mita*	*Kushal*	*Ankush*	*Sumit*	*Rajesh*	*Total*
1	Free hand welding by operator	9	8	10	7	10	6	7	9	66
2	Play in tip	10	8	8	8	9	7	8	6	64
3	in accurate position of job	7	8	9	7	10	8	7	8	64
4	Feed roller pressure high	10	9	8	9	8	4	7	7	62
5	Play in slider	10	7	9	7	5	8	6	8	60
6	High hardness of wire	10	9	5	6	5	7	7	6	55
7	Wire feed excess	9	6	1	8	8	9	7	6	54
8	Inadequate on the job training	6	8	8	7	6	3	8	7	53
9	Operator fatigue	9	6	7	8	4	6	5	7	52
10	Excess stick out	5	7	5	10	5	8	5	7	52
11	Gap in matching parts	9	8	8	7	4	3	8	4	51
12	Unskilled manpower	9	8	5	8	2	4	8	6	50
13	Voltage NG	9	4	9	9	2	2	8	7	50
14	operator health	8	8	5	8	2	7	6	5	49
15	Uneven profile of BOP	8	6	4	8	6	4	7	4	47

Table 7 displays the score of each defect based on the 'weighted score method'. This is now clear that the 'zig-zag welding' is a consistent and a top defect of the month. Infact, pareto chart already showed it to be the top defect but the 'weighted score method' confirmed it be a consistent one. In-fact if one looks at the score of zig-zag welding, then it is far ahead in comparison to the second and third. Since the top and consistent defect is now known to us, we can now use different tools to find out the root cause of the defects. So, the team started the journey to discover the causes which generated the defect. To find out the initial causes or list of probable causes, we started with brainstorming. The entire team sat together in 3 intervals and generated the multiple probable causes.

A brainstorming activity was conducted in the organisation which resulted 67 probable causes. Each cause was further analysed to find out the potential cause (Table 1). The team used the nominal group technique and ranked each of the cause individually based on the expertise and considering the data and scenario within the organisation. After rating the probable causes through nominal group technique, the team selected top 15 causes for further analysis and listed them as the potential causes (Table 8).

Further, a fishbone analysis (Figure 5) was done on the obtained potential causes (Table 8) to understand the relation of 6Ms. All the potential causes were grouped based on their 6M category and were further analysed through validation (Table 9). The team was sub-divided to validate each and every potential cause and then based on the result, the team came out with certain main causes.

Table 9 Validation of Potential causes

Validation			
Potential causes	*Standard*	*Actual*	*Remarks*
Free hand welding by operator	Gun to be placed on holder	Free hand welding	Valid
Play in tip	No play	No play	Not valid
Position of job	Job to be placed on fixture	Fixture wear and tear	Valid
Feed roller pressure high	As per spec	High	Valid
Play in slider	No play	No play	Not valid
High hardness of wire	As per spec	As per spec	Not valid
Wire feed excess	As per spec	As per spec	Not valid
On the job training	As per skill matrix	As per skill matrix	Not valid
Operator fatigue	No fatigue	No fatigue	Not valid
Excess stick out	As per spec	As per spec	Not valid
Gap in matching parts	No gap	No gap	Not valid
Unskilled manpower	As per skill matrix	As per skill matrix	Not valid
Voltage NG	As per spec	Varying	Valid
operator health	No fatigue	No fatigue	Not valid
Uneven profile of BOP	As per spec	As per spec	Not valid

The use of validation (Table 9) was a very successful activity for the team and the project, as they were able to find out the relevant main causes for the problem. All the potential causes were analysed on the shopfloor. The team visited the actual place and noted the observation for every potential cause and found that there for such potential causes which were not as per the standard and thus they have a very high probability for causing the zig-zag welding.

For all the four obtained main-causes, the team did a why-why analysis. The why-why analysis helped the team in further analysing the main cause and getting the root cause for each main cause.

Table 10 Why – why analysis

Why – why analysis	
Why 1	Free hand welding by operator
Why 2	Holder for welding gun was not available
Why 3	No space to fix the holder on booth
Why 4	It was not the part of initial design of booth
Why 5	Holder was not considered as necessary
Why 6	It was not used in any of the welding operations

Table 11 Countermeasure against the root cause

Countermeasure	
Counter measure 1	Holder for welding gun was made mandatory at every welding booth
Counter measure 2	Holder has been incorporated in the all the booth designs
Counter measure 3	Horizontal deployment has been done on all the modules
Counter measure 4	Training and awareness modules were developed and implemented

After the why-why analysis (Table 10), the team was able to find out the relevant route cause of the problem and the focus was shifted towards finding out the relevant countermeasures at all the levels for the obtained root-cause (Table 11). A similar analysis was conducted for the remaining of the defects identified and likewise the countermeasure for each of their root cause(s) were found.

4.5 Phase 4

4.5.1 Eliminate

These counter measures that were discovered in the discovery phase were further assessed and categorised as per the corrective and preventive actions. In this phase, the team will now plan the actions to implement these measures. The implementation of these actions would lead towards elimination of the defects for which this project and the effort has been undertaken.

These actions are planned at different levels as stated below:

- troubleshooting and containment action
- correction
- corrective action
- preventive action

Table 12 Actions planned for the root-causes

Troubleshooting and containment action	A loose welding gun block has been provided temporarily to hold the welding gun
Correction	All the parts with the defect zig zag welding shall be reworked on a separate welding station
Corrective action	A permanent holder is being designed for the all the welding stations
Preventive action	Welding gun holder is now incorporated as the part of the process design for all future developments
	All the welders and operators shall be trained in every quarter to use and maintain welding gun, machines and holders

For all the root-causes discovered in the previous phase, the above 4 actions have been planned (Table 12). For example: The main cause related to free hand welding by the operator was due to holder was not planned and used at any of the booths. Due to the absence of welding holder, the welder used to operate the welding gun from his hand only. This led to vibration and shivering and further caused zig-zag welding. To take care of such a cause and phenomena, following actions were planned.

After the planning of all these actions, a time plan has been made for the above, including the resources that would be required for implementation of these actions. Similarly, these actions and time plan was also made for the remaining 3 root causes. All these actions were discussed with management and after their approval the implementation of these actions were done.

4.6 Phase 5

4.6.1 Create

This is a very important and unique phase of this journey and the project. After the implementation of all the actions, this phase is carried out. In this phase, the analysis that has been done shall be re-tested and confirmed. The defect shall be deliberately created by introducing the root-cause within the system to further verify and validate that our analysis and finding were absolute and correct.

a The team selected module-1 manufacturing line for creation of the defect (zig-zag welding).

b It was decided that this activity shall be carried out in Shift-A of a Saturday, since being a weekend there is less customer schedule.

c Prior inventories were also made just to be on the safer side.

d The team decided that for 4 hours and till the manufacturing of 200 sub-assemblies, this activity shall be carried out.

e Now, the team introduced the root-cause within the system by removing the counter-measures.

- They removed the holder block from the welding booth
- Replaced the trained operator to a comparatively newer operator
- The fixture was made loose

- The roller pressure was set as high
- The auto-sensor regulator from the voltage panel was turned off.

f The entire welding process was re-started with the revised setting.

g The team started noting down the data.

Table 13 Result (zig-zag welding defect) – before the project vs. after the project vs. re-creation stage

Before the Project			*After the counter measure*			*During the re-create phase*		
Parts made	*Rejected*	*DPMO*	*Parts made*	*Rejected*	*DPMO*	*Parts made*	*Rejected*	*DPMO*
474	247	521,097	315	11	34,920	200	103	515,000

The data (Table 13) clearly suggests that after the counter-measure the defect got significantly reduced whereas after re-introducing the root cause within the system, the manufacturing environment turned to the previous state (pre-project) with almost equal number defects (in DPMO). Thus, we can conclude that the activity has been successful and the root-cause and counter-measure has been validated.

4.7 Phase-6

4.7.1 Stabilise

In this phase, core effectiveness monitoring of all the actions and counter-measures is being done. The team ensures that all the corrective and preventive actions has been taken and moreover, the result is being obtained. The team also does the documentation of each action and minute details of the project. Before the preparation of the final report, the team once again compares the current rejection data at the red-bin stage to the previous data of before the project (Tables 14 and 15).

Table 14 Zig-zag welding defect count – before vs. after the project

Day	*Before the project*			*After the project*		
	Parts made	*Rejected*	*DPMO*	*Parts made*	*Rejected*	*DPMO*
1	450	210	466,667	320	14	43,750
2	388	204	525,773	456	12	26,316
3	462	148	320,346	478	16	33,473
4	414	183	442,029	422	19	45,024
5	510	207	405,882	466	7	15,021
6	480	192	400,000	390	7	17,949
7	390	147	376,923	486	11	22,634
8	422	168	398,104	492	9	18,293
9	461	231	501,085	482	10	20,747
10	455	217	476,923	442	6	13,575

The data (Tables 14 and 15) clearly displays the effectiveness of the actions thus reducing the defects drastically. Moreover, when we monitored the customer defects before the project and after the project, the customer complaints were almost eliminated that were caused due to the zig-zag welding in the final assembly.

The customer complaints due to the zig-zag welding has been reduced to zero (Table 15). The organisation now enjoys a better reputation at the customer end and moreover, the morale of the employees and the management is now boosted. Moreover, the organisation has saved a lot commercially due to the project. One of the important things is all of these improvements were realised in less than 45 days from the start of the project. There were a lot of tangible and intangible benefits the organisations gained over these months of the project. Finally, the team prepared the final report of the project and submitted it to the management. The management in turn rewarded the team and also, they have provided us a long-term contract for their remaining locations. They also issued a letter of appreciation for our team.

Table 15 Customer complaints due to zig-zag welding – before vs. after the project

Day	*Before the project*			*After the project*		
	Assemblies made	*Rejected*	*DPMO*	*Assemblies made*	*Rejected*	*DPMO*
1	150	12	80,000	150	0	0
2	150	9	60,000	150	0	0
3	150	7	46,667	150	0	0
4	150	14	93,333	150	0	0
5	150	13	86,667	150	0	0
6	150	11	73,333	150	0	0
7	150	12	80,000	150	0	0
8	150	8	53,333	150	0	0
9	150	9	60,000	150	0	0
10	150	10	66,667	150	0	0

5 Results and conclusions

A thorough analysis and the effectiveness monitoring after the project revealed some significant findings and observations. These observations are quite relevant for the organisation and also for the practitioners, researchers and industries looking for a convenient problem-solving methodology. The PMDECS approach of red bin analysis has significantly:

a Reduced the in-house defects of the organisation. This result is based on the analysis of the defective PPM and defects DPMO for over 3 months (Table 16).

b Improved the capability of the process (Table 16).

c Reduced the customer complaints (Table 16).

Apart from the mentioned tangible benefits (Table 16), PMDECS approach also results into many intangible benefits. If compared to some of the famous problem-solving methodologies like Six Sigma etc., this approach is much affordable and convenient to MSMEs as:

a It focusses on problem generation at source rather than customer complaints

b It can be implemented without having an extensively educated manpower and less knowledge on statistics.

Table 16 Overall results – before vs. after the projects

Parameters (for a period of 3 months)	*Before the project*	*After the project*
In-house PPM	410,000	2,500
Process capability (Cpk)	0.57	1.52
Customer complaints	12 per month	0 per month

6 Scope, limitation and future research

This study and approach have been implemented at automotive ancillaries and automotive supply chain industries especially MSMEs. This is yet to be implemented at any OEM. Moreover, only specific processes like welding, machining and assembly processes have been covered through this method. So, still there is a lot scope of implementation of this methodology at different processes and industries other than the mentioned ones. Apart from the above-mentioned sectors, this approach has also not been used in service sector. The future researchers should also study the cost aspect of this approach is detail and also compare it with Six Sigma.

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