



## PROBLEM SOLVING TECHNIQUES AS A PART OF IMPLEMENTATION OF SIX SIGMA METHODOLOGY IN TIRE PRODUCTION. CASE STUDY

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### Abstract:

Problem solving methods – are an indispensable part of the management and improvement of production. At the turn of decades, with the development of industry, specific techniques have been implemented and refined by the leaders in this field, such as Toyota, GE and Motorola. The foundation of problem solving is to find real root cause of the problem as soon as possible, its understanding and implementation of appropriate solutions that will ensure that the problem does not occur again. This paper provides an overview of methods and techniques to solve problems in the manufacturing plant Trelleborg Wheel Systems Sri Lanka, producing pneumatic tires for light agricultural machinery. These techniques are implemented as part of the Lean Six Sigma program.

**Key words:** Problem Solving Techniques, Lean Management, Six Sigma, Brainstorming, Pattern Braking.

### INTRODUCTION

Trelleborg Wheel Systems is one of the biggest leader in premium class tires production for agricultural, forestry and industrial segments of the market. Production units are located in Europe, Asia and USA – from those places, through the distribution network, tires are shipped around the world. Production factory located in Sri Lanka is divided into two separated business units – Industrial Tires (TIT) and Light Agricultural Tires (LAT). This survey considers techniques and tools implemented in Light Agricultural Tires section. Trelleborg Wheel Systems is certified according to UNI EN ISO 9001 and UNI EN ISO 14001 standards. Apart from that, in the broad understanding, it has been decided to develop and implement lean six sigma techniques which became natural philosophy of day to day work.

Problem solving techniques can be divided into many different types, however all of them can be summarized as structured approaches which in the clear way, show what we should do to resolve it. It doesn't matter what the problem is about – but it is a matter to resolve this problem in structured way, because only in this way we can ensure fully understanding its real nature. Problem well stated means problem resolved in 50% – where commonly it is one of the biggest challenge during the development of high performance teams. Six Sigma DMAIC approach is structured problem solving technique which contains numbers of tool which can be used together or independently to resolve particular issue. This type of approach is often used in wider projects. DMAIC approach can be explained in following steps: Define, Measure, Analyze, Improve and Control.

Techniques presented below are included in Lean Six Sigma training program developed for Light Agricultural Tires division – Sri Lanka. This program is designed based on DMAIC approach; however certain tools can be use independently.

### PROBLEM SOLVING TECHNIQUES

Problem solving techniques implemented in LAT division can be divided into following types:

Global 8D (G8D) [4] – is a method developed by Ford Motor Company used to approach and to resolve problems. It originally comprised eight stages, it was later augmented by an initial planning stage. 8D follows the logic of the PDCA cycle. In LAT department, this method has been assigned to communicate claims/issues with customer/supplier. The disciplines are:

- D0: plan for solving the problem and determine the prerequisites,
- D1: establish a team of people with product/process knowledge,
- D2: specify the problem by identifying in quantifiable terms the who, what, where, when, why, how, and how many (5W2H) for the problem,
- D3: define and implement containment actions to isolate the problem from any customer,
- D4: identify all applicable causes that could explain why the problem has occurred. Also identify why the problem was not noticed at the time it occurred. All causes shall be verified or proved,
- D5: using pre-production programs, quantitatively confirms that the selected correction will resolve the problem,

- D6: define and Implement the best corrective actions,
- D7: modify the management systems, operation systems, practices, and procedures to prevent recurrence of this and all similar problems,
- D8: recognize the collective efforts of the team.

Quick Response Quality Control (QRQC) [4] – is a method developed by Nissan and derived by Valeo. Typically it is problem solving management and mainly used to deal with problems on a day-to-day basis to improve shop floor indicators (customers concerns & internal scrap rate, OEE, accident rates, breakdowns, etc.). In LAT department, this method has been assigned to resolve day-to-day issues, and as a knowledge data base. Idea of this method is that from the place where problem occurs, resolving should start on the as low as possible level – from line a operator, going up through a setter, a supervisor and finishing on an engineer level. Of course this method requires involvement of team, but simple issues can be spotted and resolved directly by an operator. Typical expected time to resolve a problem is 24 h. There are a few basic principles in this methodology:

- quick reaction: as soon as the problem occurs,
- real place: investigate problems on the shop floor to find out actual causes,
- real people: involve operators from the process where problem occur,
- real parts: analyze defective parts and compare with good one,
- real data: use data collected to perform the problem analysis (NOK parts history charts, parts & process characteristics measurements, etc.),
- logical thinking: Use a logical approach to the process - man, machine, method, material, and environment.
- on the job training: management should be involved in the QRQC approach to give advices, congratulate teams, and ensure that QRQC is maintained and efficient.

A3 – is a structured problem solving and continuous improvement approach developed by Toyota and typically used by lean manufacturing practitioners. It is a simple and strict approach, systematically leading towards problem solving over structured path, based on the principles of PDCA. This method has been introduced to resolve problems, where solution requires deeper analysis and, a story telling approach, to presents in the structured way findings and analysis to entire team.

Toyota’s insight many years ago that every issue an organization faces can and should be captured on a single sheet of paper [3]. This enables everyone touching the issue to see through the same lens. While the basic thinking

for an A3 follows a common logic, the precise format and wording are flexible, and most organizations tweak the design to fit their unique requirements.

The A3 is like a résumé that can be adapted in layout, style and emphasis according to the person seeking the job and the type of job being sought. Practitioners can adapt the format to fit the requirements of each situation.

On a single page, an A3 typically includes the following elements:

- title – names the problem, theme, or issue,
- owner/date – identifies who “owns” the problem or issue and the date of the last revision,
- background – establish the business context and importance of the issue,
- current conditions – describes what is currently known about the problem or issue,
- goals/targets – Identifies the desired outcome,
- analysis – analyzes the situation and underlying causes that have created the gap between the current situation and the desired outcome,
- proposed countermeasures – proposes some corrective actions or countermeasures to address the problem, close the gap, or reach a goal,
- plan – prescribes an action plan of who will do what when in order to reach the goal,
- follow-up – creates a follow-up review/learning process and anticipates remaining issues.

These A3 elements follow natural and logical sequence. The links among the problem, its root causes, goals, the actions proposed to achieve the goal, and the means of judging success are clear and easy to understand.

**PROBLEM SOLVING TOOLS**

5WHYS – is a method for pushing people to think about root causes, which prevents a team from being satisfied with superficial solutions that won’t fix the problem in the long run [2]. To prepare 5 why analysis we have to:

- select any cause (from cause and effect diagram or a tall bar on a Pareto chart) – in the same time we have to make sure that everyone has a common understanding of what that cause means (“Why 1 “),
- ask “why does this outcome occur”? (“Why 2”),
- select one of the reasons for Why 2 and ask “why does that occur”? (“Why 3”),
- continue in this way until you feel you’ve reached a potential root cause.

One important thing is that there is nothing sacred about number 5 – sometimes we may reach root cause after two or three whys, sometimes we will have to ask why much more than 5 times [2].

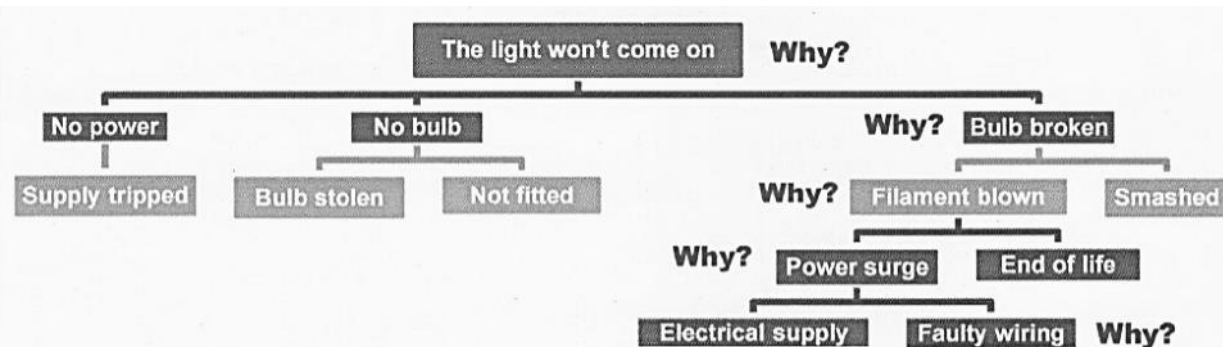


Fig. 1 5WHY analysis

If a problem or problems are going to be fixed, the real root cause needs to be understood. Sometimes it is useful to randomly select 2-3 real failures in the process and to investigate them in much more detail, using '5 Why's' – a simple but effective technique (Fig. 1) [5].

Brainstorming – in Six Sigma projects, brainstorming is often used at the beginning of the Analyze phase. Whilst 5 Why's can be used to investigate specific failures, brainstorming can be used to identify a range of potential root causes for a particular type of failure [5].

A brainstorming session needs careful facilitation. If ideas are slow, than the facilitator can use "prompting question" to help the group focus on a specific area. If someone is feeling unable to participate, the facilitator needs to help them to do so. The team should represent several levels of the organization since this helps to capture the different impressions people have of the problem [3].

There are a few success factors which have to be considered during brainstorming [4]:

- strive for quantity,
- don't pass comment or judgment,
- build on others' ideas,
- capture exactly what's suggested,
- do it when fresh,
- stimulate the group when ideas dry up or get stale – try pattern breaking tools.

Brainstorming can be performed in a few different forms [4]:

Free Form:

- everyone is free to contribute at any time,
- best for building on other's ideas but can become dominated by a minority of members & go off track.

Round Robin:

- each member contributes an idea in turn,
- get's everyone involved but members can spend more time worrying about their next contribution than listening to each other,

In Silence:

- all members write out their ideas on Post-Its in silence,
- get's everyone involved, quick & efficient but lacks an opportunity to build on others ideas.

Hybrid Method:

- start with 10 min in silence (1 idea per Post-It),
- each member explains his/her ideas in turn as (s)he sticks them to a wall,
- team, have an opportunity to Free Form at any time as an idea is explained.

Pattern Breaking – are the set of tools to stimulate ideas during brainstorming session. They can be grouped in 5 different types (Fig. 2), (Table 1) [1, 4]:

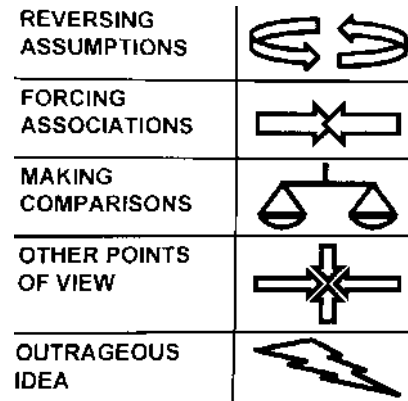


Fig. 2 Patter Breaking approach

Ideas filtering and consolidating [4] – After brainstorming session, there may be a large number of ideas to make sense of. These may:

- be fuzzy or unclear,
- be poorly stated,
- be more or less abstract,
- have different levels of detail,
- contain more than one Idea,
- be wording similar ideas differently.

Affinity diagram is a visual tool, which can organize and group ideas. During building such diagram, we have to:

- ensure all ideas/concepts are on Post-Its,
- have each Post-It stuck onto a large surface (wall),
- get the team to take each Post-It in turn and group similar ideas into logical or conceptual groups:
  - first pass works best in silence,
  - create a new line for each new idea,
  - more abstract towards top.

Table 1  
 Patter Braking types

Tool	REVERSING ASSUMPRION	FORCING ASSOCIATION	MAKING COMPARISON	OTHER POINTS OF VIEW	OUTRAGEOUS IDEA
Set the Trigger	List some of the basic assumptions that would be most provocative if not true	Pick a technology or service totally alien to the team & consider how it tackles its basic challenges	Ask what unrelated systems (e.g. in nature) have dealt with the same basic challenge	List the stake holders connected with the problem or opportunity	List some things we would never do. Push this to the point of absurdity
Create the Concept	Reverse these assumptions and see where this leads the team.	See how analogous problems have been solved in this arena	See how the team might relate these ideas to their own problem	Deliberately look at the situation from their perspective and see what arises	Look for useful concepts behind the absurd ideas
Example	It is often assumed that working faster leads to more mistakes. This is a fallacy as the extra discipline needed to work faster actually reduces mistakes (SMED)	If you are an engineer look at service and vice-versa	Reduce drag on aerodynamic surfaces by adding riblets or 'sharkskin' protrusions	Particularly useful in zones of conflict – e.g. industrial disputes Try looking at business problems purely from a customer perspective – e.g. budget airlines	'Sailing' in space World wide web

- from these groups, the team works toward a list of clearly defined concepts by discussing groups and assigning headings,
- slice and dice a high level concept into two or more specific concepts if required.

Ideas prioritization & selection – When ideas are generated, it is necessary to prioritize and select the one which from the group point of view has to be reviewed/implemented on the first place. There are number of tools for idea prioritization – below are presented major ones, which have been implemented in TWS LAT Sri Lanka.

Ease/Impact [4] – it is very simple and great team tool – especially in absence of hard data to evaluate ideas (Fig. 3). This method allows to choose solution which is easy to achieve and has the highest impact as well as to avoid hard achievements with low impact.

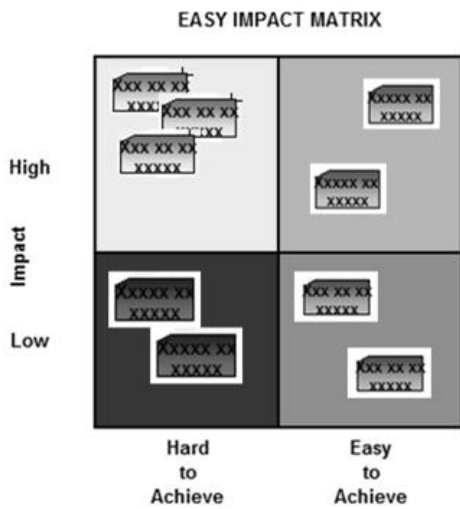


Fig. 3 Patter Breaking approach

Cause and effect (C&E/fishbone or Ishikawa) diagram (Fig. 4) [2, 3] – is used to help teams push beyond symptoms to uncover potential root causes; to ensure that a balanced list of ideas have been generated during brainstorming or that major possible causes are not overlooked as well as to provide structure to cause identification effort. To prepare C&E diagram we have to name the problem or effect of interest – writing it at the head of a fishbone. Major categories have to be decided creating basic diagram –

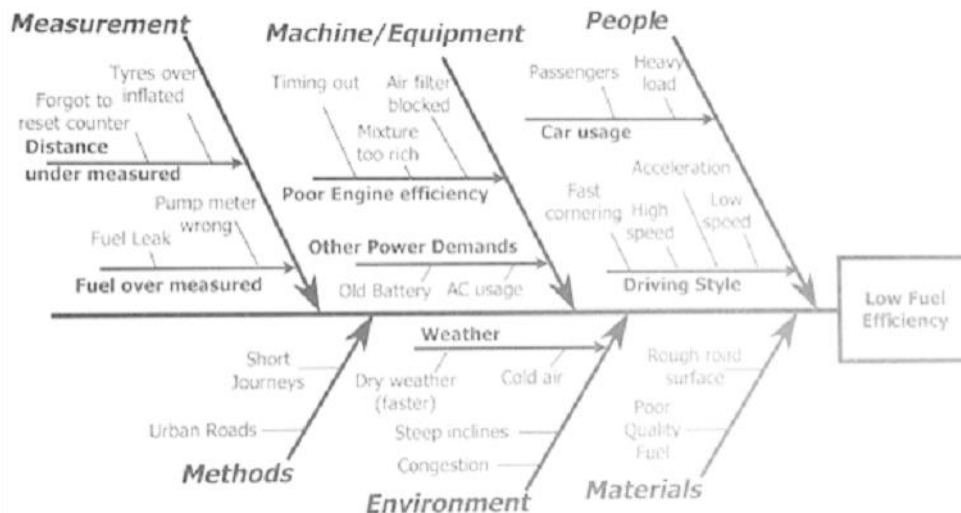


Fig. 4 Patter Breaking approach

typically include 6Ms – manpower, machines, materials, method, measurement, Mother Nature (environment). After brainstorming and creating more detailed diagram – potential cause of failure can be selected.

Cause and effect (C&E) matrix (Fig. 5) [2, 4] – is used to identify a few key process input variables that must be addressed to improve the key process output variable(s). We will use it when we would like to see what effect various inputs and outputs have on ranked customer priorities. In order to create C&E matrix we have to:

- identify key customer requirements from the process map or Voice of the Customer (VOC) studies,
- assign priority score to each output according to importance to the customer,
- identify all process steps and key inputs from the process map,
- rate each input against each output based in the strength of their relationship,
- cross – multiply correlation scores with priority scores and add across for each input,
- focus on variable relationship with the highest total score – especially on those where there are acknowledge performance gaps.

Rating of Selection Criteria	8	7	8															
Selection Criteria	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15			
Process Inputs																		
				$(3 \times 8) + (1 \times 7) + (1 \times 8) = 39$													Total	
1	Idea 1	3	1	1														39
2	Idea 2	9	1	1														87
3	Idea 3	1	0	0														8
4	Idea 4	3	0	9														96
5																		
6																		
7																		

Fig. 5 C&E Matrix

Pugh Matrix (Fig. 6) [1, 4] – is used for evaluating multiple options against each other, in relation to a baseline option known as the Datum. The method was invented by Stuart Pugh – University of Strathclyde in Glasgow, as an approach for selecting concept alternatives. Why is it useful:

- better to spend time up front ensuring we have the right Idea/Concept than wasting time later on trying to make a bad Idea/Concept work,
- great team based tool,
- enables team to focus on different aspects of the Idea/Solution in turn,
- more creative and evolutionary than C&E Matrix.

All tools and techniques are implemented selectively based on developed training program.

**SUMMARY**

Light Agricultural Tires production plant in Sri Lanka is a place which through the past years has been developed in basic lean tools such as 5S and SMED. In order to be more competitive on the market, nowadays it is not enough to use only simple Lean principles, but it is required to develop productions system to the level where all aspect of production are clear, visible and easy to understand. On top of that in case of any potential production issues – entire team has to be able to find root cause as soon as possible with proper, deep statistical or logical analysis. Lean Six Sigma development program has started to be introduced in May 2014. Since this moment, scrap level in tire curing area has been reduced at about 12% and entire scrap level for plant at about 21%. As a General manager and Master Black Belt responsible for entire plant, leading innovation projects and implementation of Lean Six Sigma ideology in the plant, I encountered the problem of a proper understanding of the basic Lean Six Sigma tools – therefore a training program has been developed to ensure that these tools will be expertly and properly used. Starting from the waste reduction, going through basic Six Sigma tools and finishing on advance analytical approach to the process, the training program covers all methods of its implementation, the errors that can occur during the analysis, the problems that result from lack of proper understanding of the problem and from the same analysis as well as a detailed explanation of the use of computer-aided engineering statistical software. All presented tools and techniques were also part of the Lean Six Sigma projects in Trelleborg Sealing Solutions division that have been positively completed and brought to the company's high annual profits – problems have been solved, implemented solutions have been monitored till now.

Features	Concept/project/idea	Idea 1	Idea 2	Idea 3	Idea 4	Idea 5	Idea 6
Customer Impact	D A T U M		W	B	W	W	W
Savings potential			W	B	W	W	W
Low investment			W	B	B	W	W
Strategic alignment			S	S	W	B	W
Speed of delivery			W	S	S	W	S
Team availability			S	S	W	W	W
Probability of success			W	S	W	B	W
Sum of B's			0	3	1	2	0
Sum of W's			5	0	5	5	6
Sum of S's			2	4	1	0	1

B=Better, W=Worse, S=Same as Datum

**Fig. 6 Pugh Matrix**

Pugh method steps:

1. Prepare a list of 'Requirements for Success' against which the Ideas/Concepts are to be judged. These are termed the CTS's & can usually be derived from the VOC, Stakeholder analysis or SIPOC,
2. Develop a way to sketch/represent ideas/concepts developed so far,
3. Choose a DATUM Idea/Concept (baseline) with which all other Ideas/Concepts are to be compared,
4. Compare the Ideas/Concepts with the Datum for each CTS using the Pugh Matrix – Determining if it is Better, Same, or Worse,
5. Identify the best Ideas/Concepts to take forward,
6. Combine best Ideas/Concepts to make new hybrids incorporating the strongest ideas,
7. Chose a new Datum and compare new hybrids with new Datum to select best hybrid,
8. If the selected hybrid is bad loop back,
9. If the new hybrid is good take this forward to detailed solution stage,

Supportive and statistical tools – Lean Six Sigma training program, require not only an extensive understanding of waste reduction, but also statistical approach to the processes, therefore entire program has been built as follow:

- waste reduction – all set of lean tools,
- graphical analysis – such as Pareto Chart, Histogram, Box plot, etc.,
- MSA – measurement system analysis,
- capability study,
- SPC – statistical process control,
- hypothesis testing,
- DOE – design of experiments.

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