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AN INVESTIGATION OF THE EXTENT TO WHICH THE SEVEN BASIC QUALITY TOOLS ARE USED TO EFFECT IMPROVEMENTS IN QUALITY AND PRODUCTION PROCESSES AT A BATTERY MANUFACTURING COMPANY IN SOUTHERN AFRICA

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ABSTRACT

This is a case study that investigates the extent to which the seven basic quality tools are used to effect improvements in quality and production processes at a battery manufacturing company in Southern Africa, hereafter referred to as Company B. The company manufactures lead acid batteries for the manufacturing, mining and automotive sector. The study is a case study conducted at one of the branches of the company and it analyses departments and processes where these tools find application. It also looks at the scope of application and the logical approach followed in identifying the causes of quality problems. Quality and process improvements derived from the use of the tools were discussed. The study revealed that the tools are applied throughout the company from sourcing of raw materials to the delivery of finished products. Benefits enjoyed by Company B include low rejects and reworks, better customer/supplier relationships and teamwork within the company workers. Although Company B enjoys these benefits, it experiences challenges in applying the tools in a structured manner.

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1 INTRODUCTION

Company B was established more than 80 years ago and is the leading battery manufacturer in Southern Africa. It manufactures a large range of automotive and non-automotive batteries. In the non-automotive category it makes miner lamp, marine, mining, leisure, standby and solar batteries. The batteries are manufactured for the Original Equipment Manufacturers (OEM) and the aftermarket. On the local market the batteries are distributed through franchise centres. Company B exports its products to more than 30 countries worldwide. The company is strongly integrated and moulds plastic components and recovers lead from spent batteries in compliance with the environmental controls dictated by ISO14001:2004. These components are then used in subsequent manufacturing processes. The company has adequate technical capability to design and build batteries that meet OEMs' quality and performance standards. Mercedes Benz, Toyota, Nissan, BMW, Volkswagen, Renault, Nissan Diesel and MAN are some of the beneficiaries. Mines, power generation and telecommunication companies rely on Company B standby batteries.

All batteries are manufactured in accordance with ISO9001:2008, VDA6.3 and ISO/TS 16949:2009 quality systems. These quality systems are sustained through investment and application of modern manufacturing equipment, product testing equipment, quality standards and environmentally friendly practices and programmes. The Chief Executive Officer of Company B has shown commitment through the pronouncement of a company vision, quality and environmental policies. In addition Company B has recorded a number of quality listings and awards. This study investigates the extent to which the basic quality tools are used to effect improvements in quality and production processes at the battery formation plant of Company B.

Bamford and Greatbanks [1], define a process as an activity that takes in an input and transforms it into an output. On the other hand McQuarter et al [2] define quality tools as practical methods, skills, means or mechanisms that can be applied to a particular task. There are seven practical methods or tools used in statistical process control, sometimes referred to as the 'maginificent seven'[3]: (1) control charts, (2) histograms, (3) Pareto charts, (4) check sheets, (5) process flow diagrams, (6) scatter diagrams, and (7) cause-and-effect diagrams. They were first emphasized by Ishikawa (in the 1960s), who is one of the quality management gurus [4]. Most of these tools are statistical and/or technical in nature [3]. They are used to facilitate positive change and improvements. They can be used in all phases of production process, from the beginning of product development up to product marketing and customer support [5]. The application of each of these basic quality tools is given in Table 1.

Bunney and Dale [7] suggest that the use and selection of quality management tools and techniques are vital to support and develop quality improvement processes. According to McQuarter et al [2], quality management tools play a key role in a company-wide approach to continuous improvement, and allow:

- process to be monitored and evaluated;
- people to solve their own problems;
- a mindset of continuous improvement to be developed;
- a transfer of experience from quality improvement activities to everyday business operations;
- reinforcement of teamwork through problem-solving.

Table 1: The Seven Basic Quality Tools [4]

Tool	Definition	Application
Check sheet	A form used to collect, organise, and categorize data so that it can be easily used for further analysis.	Data acquisition
Histogram	A graphic display of the number of times a value occurs.	Data acquisition
Control chart	A graph of time-ordered data that predicts how a process should behave.	Data acquisition
Process flow diagram	A graphical illustration of the actual process.	Data analysis
Pareto diagram	A bar chart that organises the data from largest to smallest to direct attention on the important items (usually the biggest contributors).	Data analysis
Scatter diagram	A graphical tool that plots one characteristic against another to understand the relationship between the two.	Data analysis
Cause and effect diagram	A schematic tool that resembles a fishbone that lists causes and sub-causes as they relate to a concern, also known as Fishbone diagram or Ishikawa diagram.	Data analysis

McQuarter et al [2] further argue that before the above benefits are derived from quality tools there are also nontechnical aspects that should be in place. These include:

- a full management support commitment;
- an effective, timely and planned training;
- a genuine need to use the tool;
- clear aims and objective for use;
- a co-operative environment; and
- support from improvement facilitators.

Sousa et al [8] state that there is a great variety of quality tools since there are many quality improvement paradigms to help organisations improve their products or services. Even similar organisations have different needs and consequently use different quality tools. These tools generate important information that could help eradicate the relevant problems and improve not only the product quality, but also the quality of management practices, Ahmed and Hassan [9]. Firms with clear implementation plans of quality tools can secure better performance than those without. According to Paliska et al [5], a continuous quality improvement process assumes, and even demands that a team of experts in the field as well as company leadership should actively use quality tools in their improvement activities and decision making process. Paliska et al [5] moreover argue that quality tools are required in any firm irrespective of its size. However, the choice of any tool or method is not just automatic, but instead it is situation specific [9]. Many companies have used tools without giving sufficient thought to their selection and have then experienced barriers to progress [4]. Another challenge is that the tools are not there to solve the existing or would be problems, but are used as means of identifying the problems or strengths in specific terms through systematic manners. Therefore, the users must understand the applicability of the tools before using them.

2 METHODOLOGY

Information was collected by a University of Johannesburg Industrial Engineering Student from Company B. She had interviews with the production manager, quality manager and internal quality auditors. The student was attending her final year of undergraduate studies and had completed at least two courses in the field of quality. To gain access to the information required in the study, the student undertook the following:

- she arranged appointments with the production manager, quality manager, internal quality auditors and full-time machine operators in charge of production line;
- she had one-on-one interviews with the above personnel; and
- verified the answers given by the interviewees by taking informative tours of the production floor and managerial offices of the plant.

Company B operates from four sites that are involved in manufacturing of automotive batteries, industrial batteries, moulding of plastic components and recycling of used and scrapped batteries. Lack of adequate financial resources and limited time allocated for the study restricted the project team to do their research at the battery formation plant. The scope of the study encompassed the transportation of dry batteries from the plastic plant to the battery formation plant, dry battery warehouse, formation line and the distribution of formed batteries to customers and distribution centres.

3 FINDINGS

According to Ilkay and Aslan [10] motivations for quality system implementation can be grouped as internal or external. Internally motivated companies are interested in the continuous improvement of quality and their perceived benefits are increased productivity, improved efficiency, reduction in cost and waste, better management control and increased employee motivation. External benefits manifest in the form of increased; sales and market share, opportunity for new markets, new customers, customer satisfaction, and company's reliability and image. Company B's motivations to improve quality and production systems are driven by both internal and external factors. To realise these benefits, Company B to some extent exploited the basic quality tools. Section 3.1 to 3.7 explain how Company B benefited from the use of these quality tools.

3.1 Check Sheets

Company B used check sheets throughout the battery formation line and the checks were done daily on:

- non-conforming parts;
- production machinery;
- calibration equipment;
- machine parameter;
- tool change;
- personal protective equipment;
- training; and
- housekeeping (5s).

Table 2 shows data captured in the production control section of the battery formation. Additional data captured on the check sheet is on; non-conforming parts, error proofing, training and lean management tools. The check sheet also has provision to take corrective action on non-conforming products and activities.

Table 2: Daily Layered Check Sheet - Battery Formation

			Mon		....		Sun		Summary
Responsible	**B. Production Control**	**Shift**	**Y/N**	**N/A**	**Y/N**	**N/A**	**Y/N**	**N/A**	**Total nonconforming/week**
Operator	**First Offs**	A							
	Was a first-off completed?	B							
	Are there evidence that it passed?	C							
Operator	**Daily set up sheets**	A							
	Was the daily set up sheet completed?	B							
		C							
Operator	**Calibration**	A							
	Are all measuring equipment used on	B							
	production line calibrated?	C							
Operator	**Poke Yoke**	A							
	Are all poke yoke processes been	B							
	documented?	C							
Operator	**Machine Parameters**	A							
	Are all machine parameters	B							
	running within parameters?	C							
Operator	**Tool Change**	A							
	has any tool change been	B							
	documented?	C							
Operator	**Personal protective equipment (PPE)**	A							
	Are the operators wearing PPE?	B							
		C							

3.2 Histograms

Company B developed histograms from the data in the check sheets. They were presented to show frequency, cumulative frequency, relative frequency, or relative cumulative frequency of:

- rejects; and
- reworks.

The total rejects were recorded on monthly basis and Figure 1 shows departments where histograms were useful.

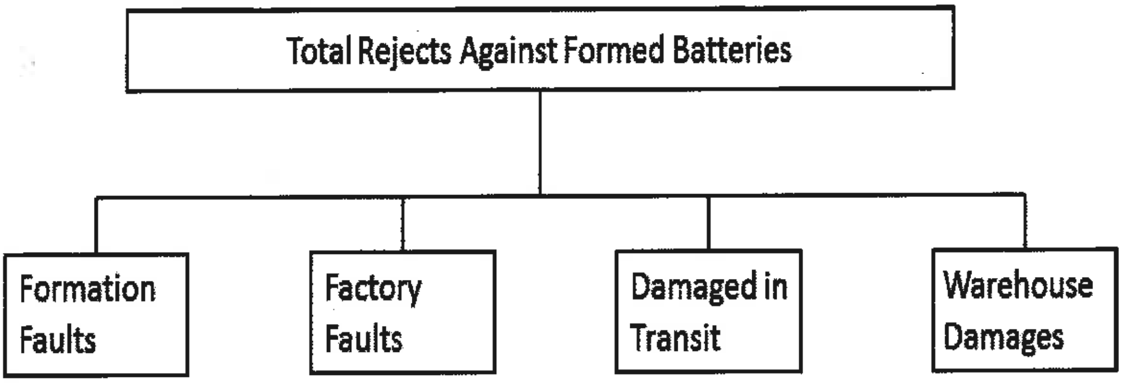


Figure 1: Departments in Company B where histograms were used

The monthly distribution was an input into the yearly graphs. The specific faults recorded in different departments are given in Table 3.

Table 3: Battery faults recorded on histograms on monthly basis

Factory Faults - recorded as a proportion of the total formed batteries		
Broken plates	Weld- partial	Cracked bridge
Incorrectly assembled battery	Loose plate	Over brushing
Poor post burn	Reverse assembly	Top short
Broken welds	COS lead run	Cracked frame/Lug
Leaking lid	Separators	Poor Neg Lug Bonding
Post lead run	Ring welds	Bent feet/plate

Formation faults-recorded as a proportion of the total formed batteries	
operational	Material handling

Damages in transit-recorded as a proportion of the total formed batteries	
No corner pieces	Damage caused by strapping
Scratches-factory fault	Post pushed in

Warehouse damages -recorded as a proportion of the total formed batteries	
Stress marks	Handling
Battery fell from forklift	Broken handles
Battery fell from rack	Battery bumped by forklift
bulging	Battery fell from conveyor

Figures 2 and 3 are a representation of the relative frequency histograms on total rejected units and total batteries damaged in transit respectively. The graphs gave management an opportunity to deduce the amount of money lost in rejects.

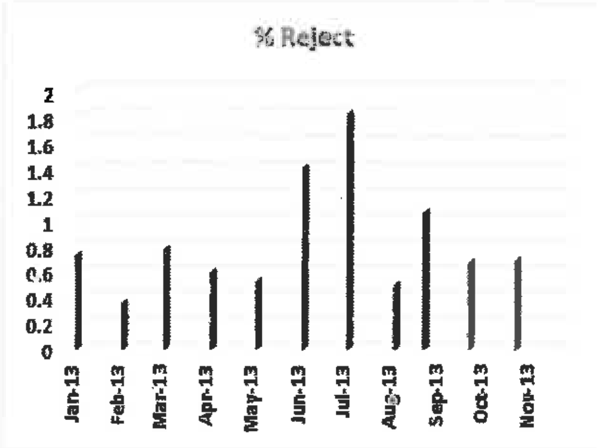


Figure 2: Percent Total Rejected Units Against Formed Batteries

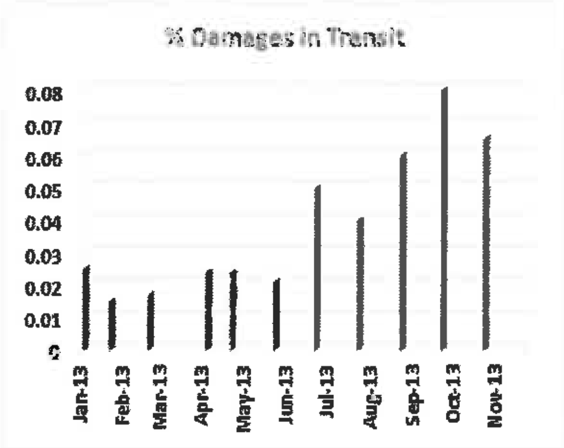


Figure 3: Percent Damages in Transit against Total Formed

3.3 Pareto Diagrams

According to Besterfield [11], Pareto diagrams have a wide application. They could be used to analyse production problems, causes, types of nonconformities, customer accounts, products giving the majority of profit, items accounting for the bulk of the inventory cost, problems accounting for the bulk of the process downtime, vendors accounting for the majority of rejected parts, customers accounting for the majority of sales, quality characteristics accounting for the bulk of scrap or rework cost, to name just but a few.

In Company B, Pareto diagrams were fairly popular. This tool was popular in capturing information associated with:

- warranty claims;
- speed shift line processes quality reports (weekly and year to date records);
- machine failures;
- reworks; and
- rejects.

This powerful tool was limited to the identification of problems in two departments. There was need to expand the scope of application.

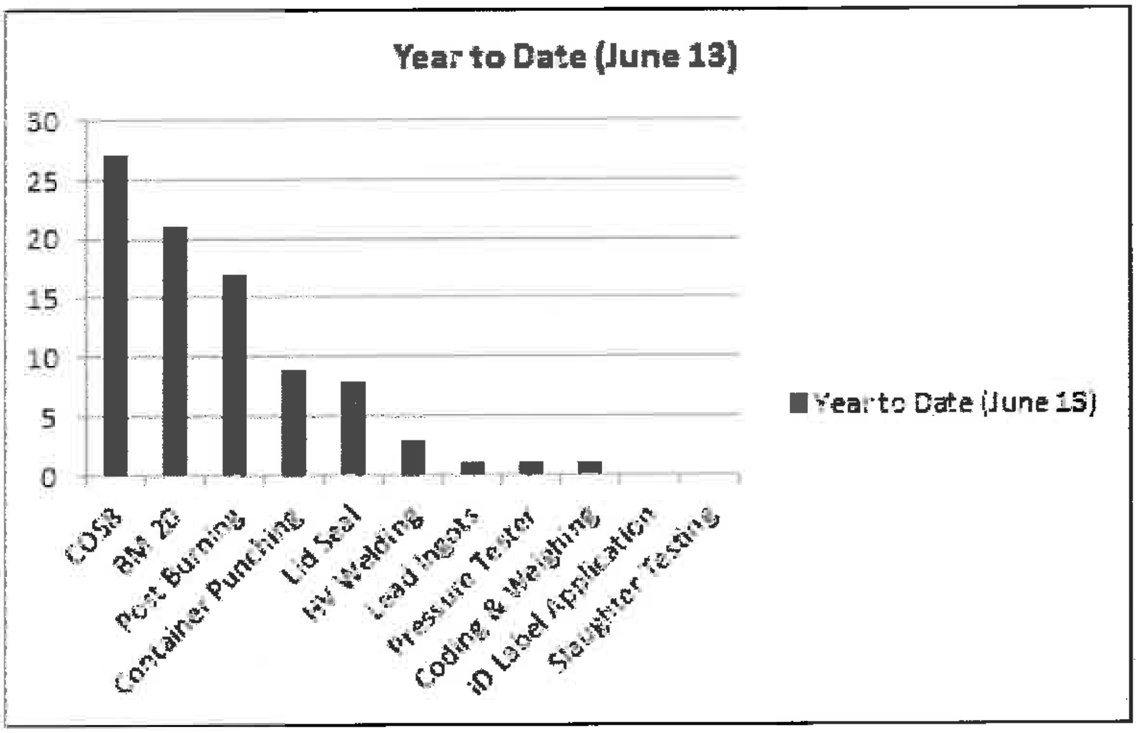


Figure 4: Pareto Analysis Based on Weekly Findings - Formation Line

3.4 Cause and Effect Diagrams

In general, the cause-and-effect diagram is a quality tool known to show the relationship between an effect and its causes. It is used to investigate either a 'bad' effect and to make action to correct the causes or a 'good' effect and to learn those causes responsible [11]. Determining all the major causes requires brainstorming by a cross-functional project team. This tool has an unlimited application in research, manufacturing, marketing, office operations and so forth [11].

Company B used the cause-and-effect diagram in conjunction with the 5 whys or on its own to identify the root causes of problems in management, quality, technical, warranty claims, battery formation line, warehouse and maintenance. Members of a cross functional team performed the root cause analysis. The process did not end with the identification of the cause, but proceeded to the problem solving stage. Figure 5 shows the stages that Company B went through in identifying and solving quality and manufacturing problems in the company.

The tool was restricted to the 'bad' effects only. It would be handy if its use had been broadened to include 'good' effects as well.

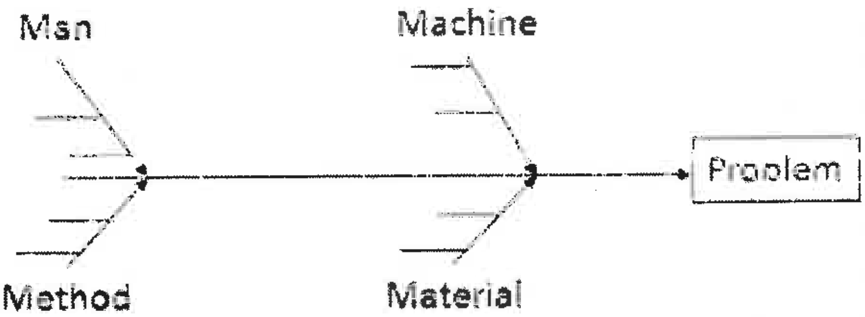
Problem Solving Process

1. Source: i.e. Management, Quality, Techical, Customer, Operator, Warehouse, Supervisor,and maintenance.
2. Problem Title: ____________________
3. Description/ Sketch/ Photo of the Problem: ____________________
4. Short term counter measures (proposed by the source): ____________________
5. Root Cause Analysis:

	5 WHYs
Problem	
1. WHY	
2.WHY	
3.WHY	
4. WHY	
5. WHY	

and/or

Cause and Effect Approach



6. Root Cause Analysis:
7. Preventive Action:

Figure 5: Cause-and-effect problem solving approach at Company B

3.5 Scatter Diagrams

According to Besterfield [11], the simplest way to determine if a cause-and-effect relationship exists between two variables is to plot a scatter diagram. At Company B, this tool was not used. Ironically Company B used the cause-and-effect diagram widely. A scatter diagram would have been useful in establishing the extent of the relationship between variables, i.e. causes and effects.

3.6 Control Charts

Control charts are an outstanding tool showing the presence or absence of assignable causes. The out of control condition indicates the need to take action to remove the cause and once the cause is removed, quality improvement or process improvement is realised. It is unfortunate that Company B did not use control charts. It is very useful when used in conjunction with other tools such as the cause-and-effect, brainstorming and Pareto diagrams.

3.7 Process Flow Diagram

The diagram shows the flow of the product or service as it moves through the various processing stations or operations. It makes it easy to visualise the entire system, identify potential trouble spots, and locate control activities. The diagram shows who is the next customer in the process, and this increases the understanding of the process. It is best constructed by a team, because it is rare for one individual to understand the entire process [11]. The diagram is enhanced by adding time to complete an operation and the number of people performing an operation.

At Company B this tool is widely used. A comprehensive process diagram for the battery formation line is given in Figure 6. Besides showing the sequence in which tasks are executed, Company B process diagrams indicate inputs and outputs and people responsible at each stage.

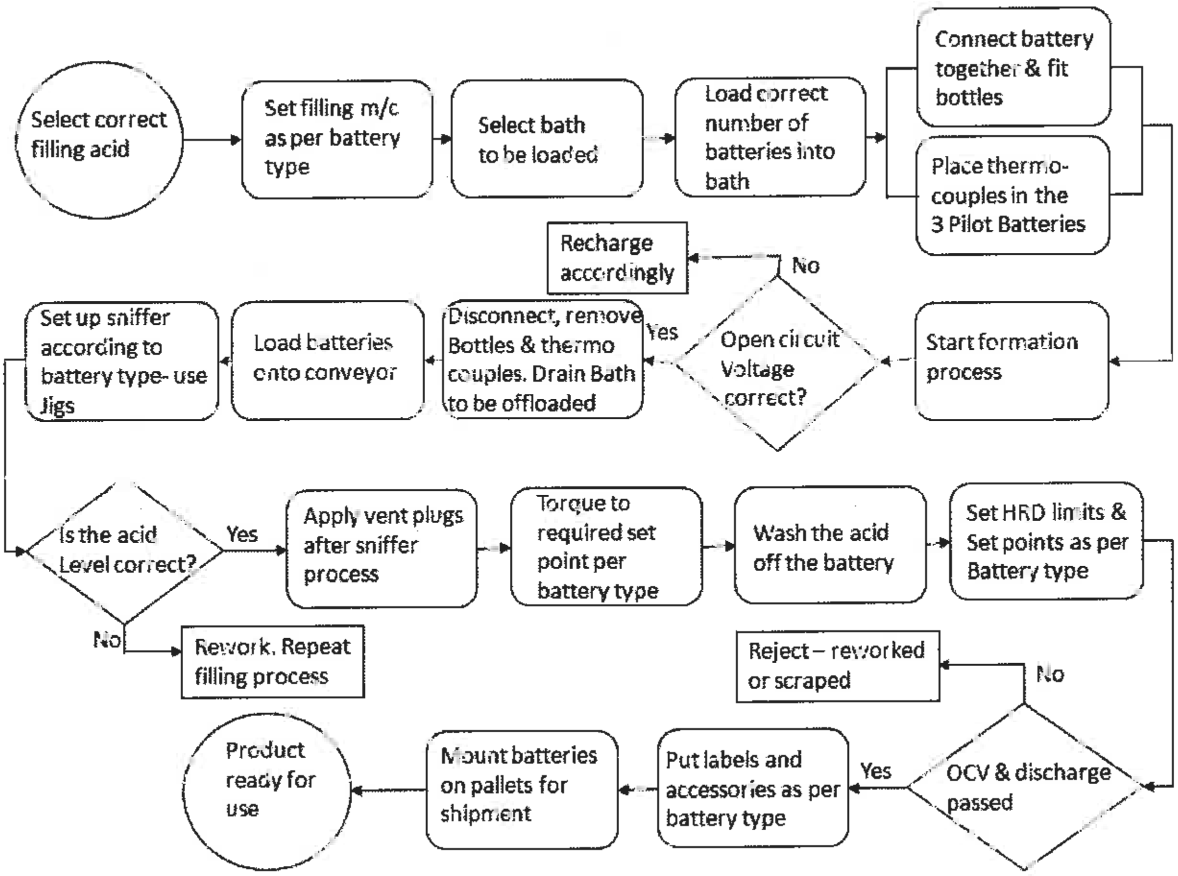


Figure 6: Flow Process Chart - Battery Formation

4 CONCLUSION

The check sheet, flow process chart, and cause-and-effect diagram were popular at Company B, and were exploited throughout the production stages at the battery formation plant. These tools were largely used in collecting data, analysing and identifying the causes of the problem. The performance perspectives for which these tools were used to investigate are many and include quality management, inventory management, plant maintenance, warranty and production management.

Histograms and Pareto charts were moderately utilised. The quality program at Company B did not exploit scatter charts and control charts.

In addition to the above tools Company B also used other tools such as 5whys and pie charts. The 5whys were used to determine relationships between causes in a hierarchical way. They were used in place of or in conjunction with the cause-and-effect diagrams and the pie charts were used together with Pareto charts and histograms.

Although Company B had a number of quality tools at hand, its problem-solving program lacked a structured methodology for the selection of the appropriate tools. Moreover there was no consistency in both approach and deployment.

Company B could take a leaf from Bamford and Greatbanks [1] who proposed the framework in Figure 6. This framework provides a structured approach to the application of the basic tools of quality management.

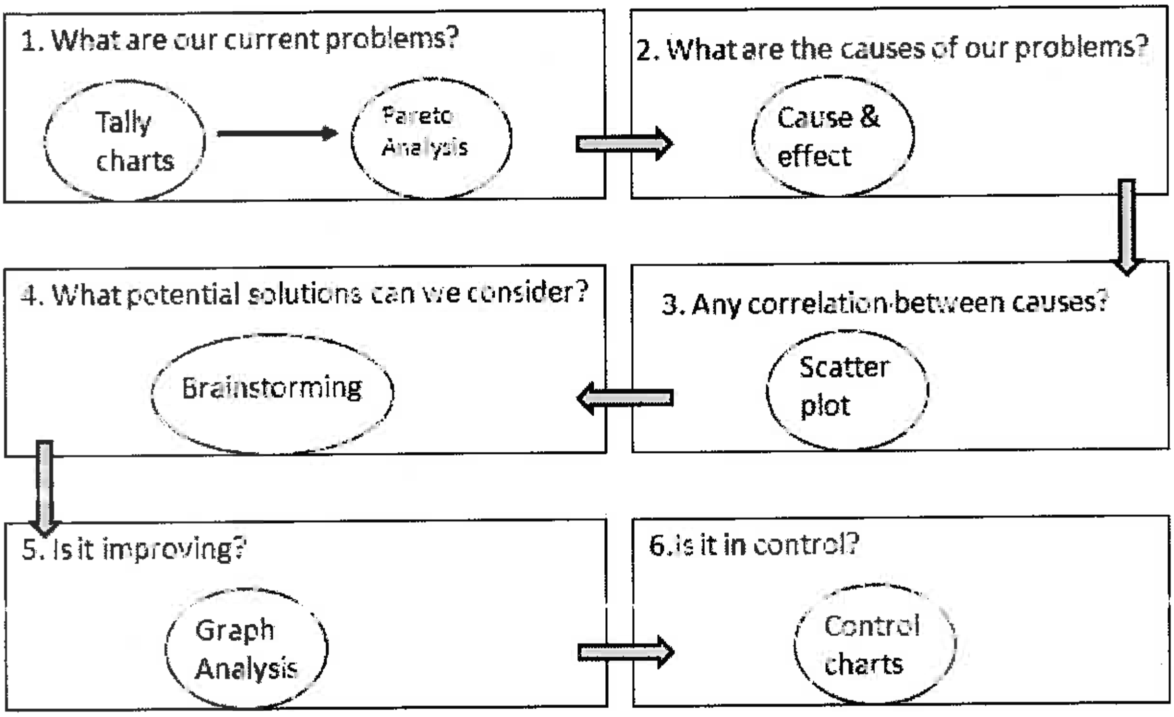


Figure 6: Structured application of quality tools [1]

The order in which the tools are applied differs depending on the process, Bamford and Greatbanks [1]. What is important is to have one tool's output being and input into the next tool.

Part of the problem was due to insufficient training in the use and application of these tools. There is need to train the users on how to link up the tools, construct the charts and interpret the results. The users also need to know the areas of business (or process) to apply the tools.

Another hindrance to the application of the tools, was the mind-set of the operators, and supervisors when introduced to quality control tools. They seemed not to appreciate the benefits derived and regarded the application of the tools as an additional workload over and above their current responsibilities.

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