



How Advanced Analytics can Minimise the Cost of Poor Quality by up to 75%

The current cost of poor quality (COPQ)

Even leading companies with ostensibly optimised individual systems and utilising the most sophisticated quality techniques may still be losing up to 30% of their product sales value through the Cost of Poor Quality (“COPQ”)*, a figure substantially more than their profits.

COPQ is one of the largest cost items in the industry. It is caused by complexity, competition and launch speeds. Everyone sees the high-profile recalls but this is just the tip of the financial iceberg. It manifests as yield failures and warranty faults and every years it costs manufacturers \$72Bn with internal costs (right first time and yields) around \$950Bn (at the lowest estimate**). This excludes non-warranty service costs such as maintenance and Product Lifecycle Management (“PLM”) and of course environmental waste, slow launch times and safety issues.

COPQ is high typically because root causes of faults are hard to identify, as well as the competitive pressure to launch ever more complex, innovative products. The state of the art of resolving faults requires many disciplines: deep engineering knowledge, structured problem-solving approach, statistical tools, IT and data science. Many organisations, even when they have all these skills available, struggle to deploy them in the right quantities when and where they need it to solve big issues and clear backlogs of lesser ones. Most of these issues are multi-million dollar problems, and time is money. Many times, a workaround is implemented and there is no 100% certainty that the fault will not reoccur. Unless the problem is fully understood and holistically considered (including throughout the supply chain), clash tolerances can mean that a tweak here to repair one issue could mean an issue occurring somewhere else.

On top of this, some of the most challenging type of issues to resolve are No Fault Found problems, where the symptoms are transient and/or intermittent. These are particularly difficult to diagnose and resolve and usually require a lot of trial and error and workaround solutions without really addressing let alone understanding the real root cause.

All of these challenges are further amplified by the challenges of managing and analysing the data required which are often dirty and/or incomplete and/or unstructured, for example manual text. Typically there is either too little or too much i.e. ‘big data’ which can be worse.

** International Journal of Engineering Dec-12 average was 20%, Wang, Bhote, Juran and Crosby cite up to 40% in some cases*

*** Warranty costs apply to certain industries, internal costs apply to all manufacturing industries, globally \$6.8 Trillion market*

The proposed solution

This paper aims to introduce a new approach and a new type of technology, as exemplified by “SigmaGuardian” enterprise software from Warwick Analytics that stems from over a decade of academic research in the US and UK and originating from six-sigma failures in complex manufacturing.

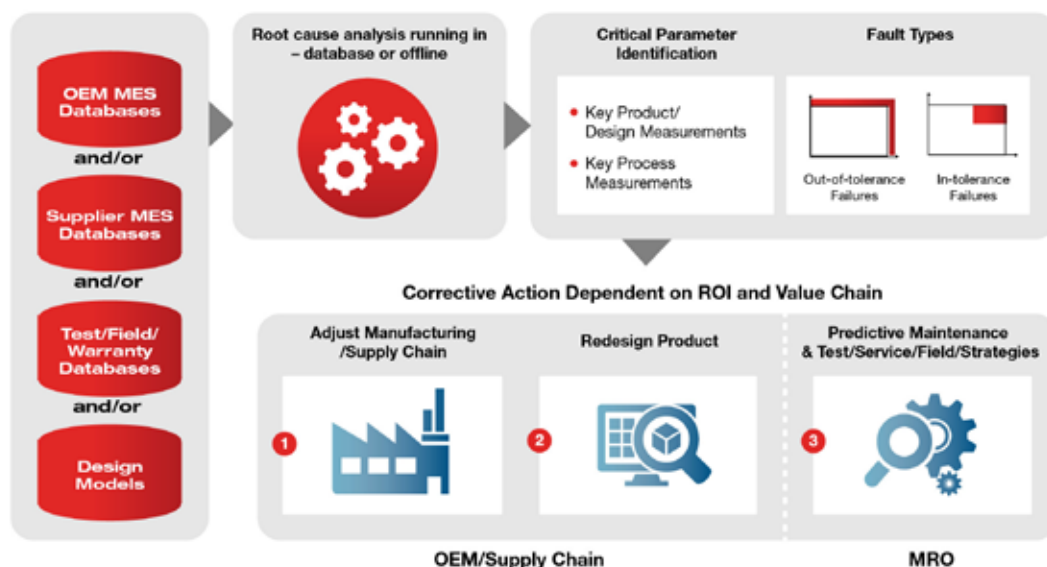
In-tolerance failure versus out-of tolerance failure

All Manufacturing Execution Systems (MES) and Statistical Process Control (SPC) look for outliers and trends which are 'out of tolerance' i.e. the specific parameter or parameters being measured in themselves are too large or small and therefore they set off alerts and alarms so that they are reworked or scrapped before they leave the factory. This causes wastage in and of itself albeit that at least there are data which provide a corrective feedback loop. However the underlying problems don't go away by doing this, and occur 'in-tolerance', in other words all of the parameters are individually within their normal bands yet the product is still faulty or develops a fault when it leaves the factory (or maybe later on in a process within the factory). Resolving in-tolerance failures is really the key to unlocking root causes.

As you can see in the Figure 1 below, the two small graphs in the top right corner show two illustrative parameters plotted against each other and the black lines which make up the square are the tolerances. The red parts of both graphs are the failure regions, i.e. where products are failing according to their parametric signatures. In the first graph, this region represents 'out-of-tolerance' failure (which can and should be picked up via MES/SPC as above) and in the second graph it represents 'in-tolerance' failures which is to say that all the parameters are within their tolerances yet products are still failing in the red region. You can see therefore that defining and locating this 'fault region' would identify not only the critical parameters causing the issue, but would quantify the requirement to obviate the problem, i.e. how to best stay out of the fault region by specific corrective action (see below).

It is possible to identify these regions by exhaustive search or manual methods, although the number of possible regions is $n!$ (factorial) because any number of of the parameters in combination could be causing the issue (i.e. the fault region can be multidimensional). The kind of technology as exemplified within SigmaGuardian has been specifically developed to identify these fault regions from in-tolerance failures as rapidly as possible and before they become statistically significant which by definition means before statistics can detect them (and before they become expensive or catastrophic). More below.

Figure 1: High level Advanced Analytics Architecture in a typical manufacturer



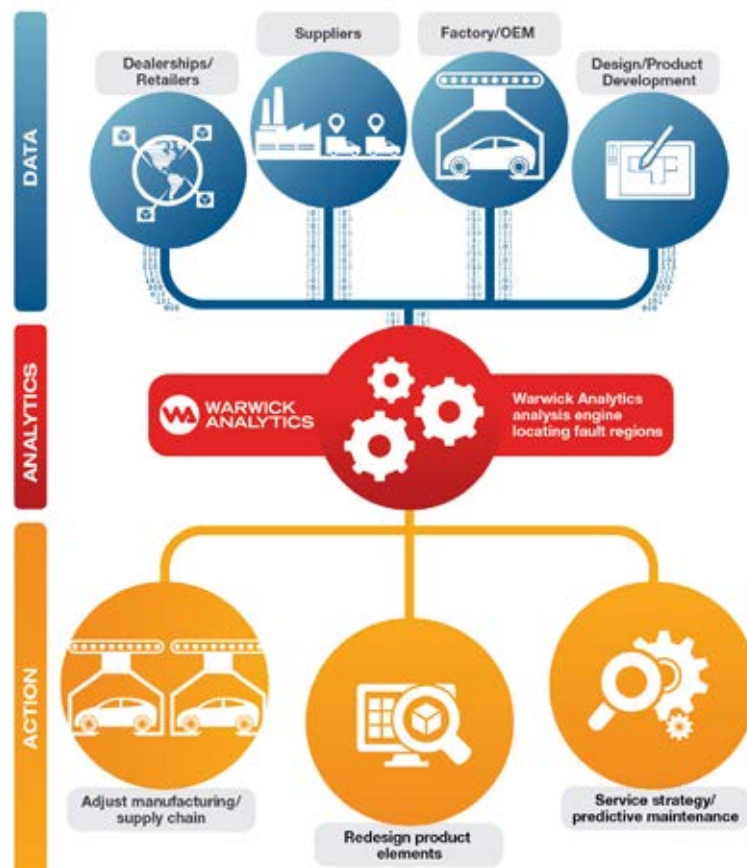
About Advanced Analytics

Advanced Analytics can be non-statistical and based on information theory, meaning it doesn't require hypotheses or multivariate analyses. It can highlight issues immediately and in near real time and will interface with all MES and ERP systems.

It works by utilising the data that manufacturers already produce (e.g. from discrete quality and process measurements and warranty data) to automatically locate the root causes of product faults and process inefficiencies and recommends the most beneficial actions without the need for hypotheses. It does all of this automatically in the background by plugging into the various factory automation systems and databases, and acts as an Early Warning and Prevention ("EWAP") system.

The key advancement of this software is that the data can be disparate, incomplete and even dirty – the software will produce precise results in a matter of seconds, thus enabling manufacturers to solve persistent problems, including No Fault Found issues, driving down their COPQ and improving quality. Normally an engineer would need to act as a data scientist, setting up hypotheses and using sophisticated statistical tools such as multivariate analysis, logistic regression or machine learning to try and solve such issues. This might take months if at all solvable. Figure 2 below shows how disparate data can be used to recommend optimal corrective actions.

Figure 2: Corrective and Preventative Actions (CAPA) diagram

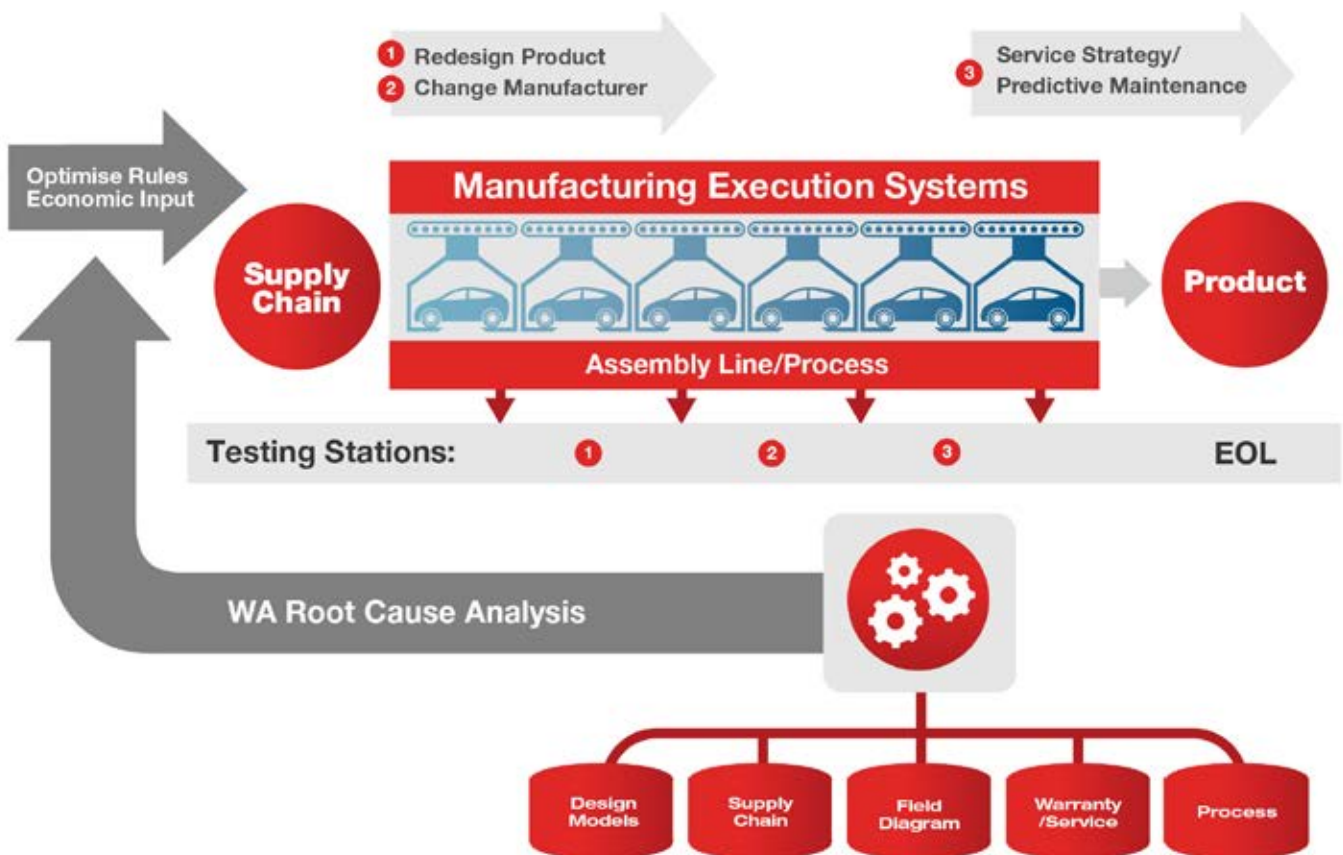


How factory and warranty issues are addressed by Advanced Analytics

Advanced Analytics can continuously identify and resolve the root causes of product faults and process failures as they occur. It will interface with all MES, PLM and ERP systems and databases.

The result is an effective quality security system monitoring and preventing defective products from being produced. The output, from the analysis, will be markers that identify either an exact root cause of failure or a parametric region pointing high probability of failure (i.e. data-driven guidance on where to look next to gather data and resolve the root cause exactly). From identifying these fault regions, engineers can work out corrective actions which are either: remanufacture (i.e. by changing the SPC manufacturing tolerances in combination), redesigning the product (i.e. by altering the tolerances in the design itself as per the fault region) or to specify precisely the products in the field which require corrective action, and the lowest fix, without having to recall the entire fleet or batch, or implement an expensive workaround. Even if the parameters being measured aren't precise or capturing the critical variables, the technique can still be practically used to obviate fault regions even without necessarily knowing precisely the physics which is the cause.

Figure 3: A typical closed feedback loop with early warning in a manufacturing plant



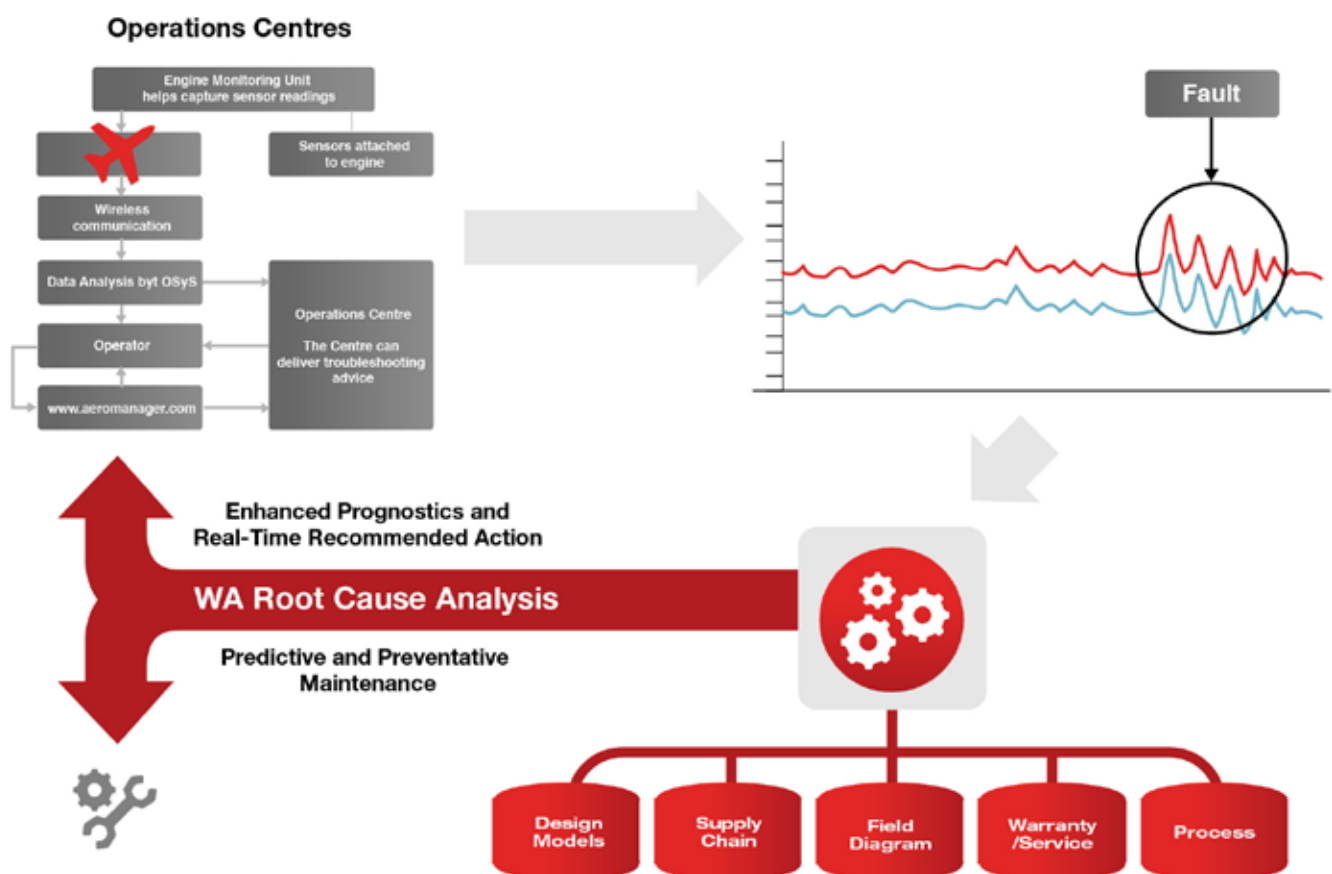
How maintenance and service issues are addressed by Advanced Analytics

Advanced Analytics can improve the availability and safety of products and aid predictive/preventative maintenance even over the entire product life cycle not just the yield and warranty periods. Advanced Analytics can:

- Optimise maintenance scheduling based on root causes analysis and prognostic indicators
- Aid predictive and preventative maintenance planning by combining diagnostic and prognostic data with attribute and/or OEM data
- Identify fixes for lowest cost rather than scheduled or workaround 'swap-outs'

This is vital in the move towards Fixed Price and Availability Contracts rather than break-fix contracts and has implications for Total Cost of Ownership and Through Life Engineering. These trends are prevalent in capital equipment including aerospace, trains, oil rigs, infrastructure and wind farms. The COPQ is therefore not just the OEM COPQ but also includes the operator costs (e.g. the airline) and therefore provides benefits to a wider group of users.

Figure 4: A typical early warning loop for a service or maintenance environment



COPQ and warranty related benefits

“This software is potentially revolutionary for the manufacturing industry. Engineering, manufacturing, and even maintenance personnel no longer have to get bogged down resolving issues or delaying product launches. Issues are resolved on-the-fly allowing the company to be more agile and cost-effective”
Head of Quality, Automotive

Manufacturers already using SigmaGuardian are experiencing:

- A 75% reduction in the cost of poor quality (exc warranty)
- A 50% reduction in warranty resolution lead time
- Savings of up to 8pc of overall sales

Figure 5: Internal cost of poor quality (excluding warranty)

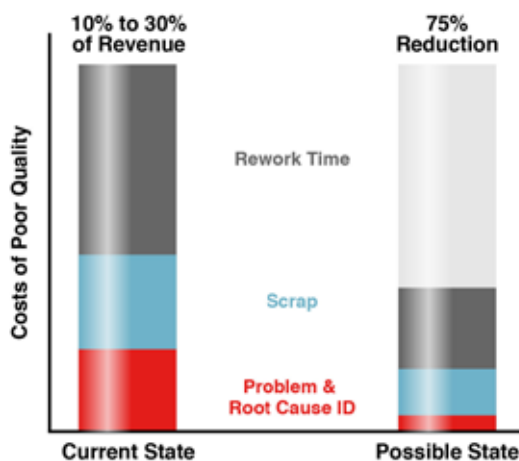


Figure 6: Warranty resolution lead time (typical automotive)

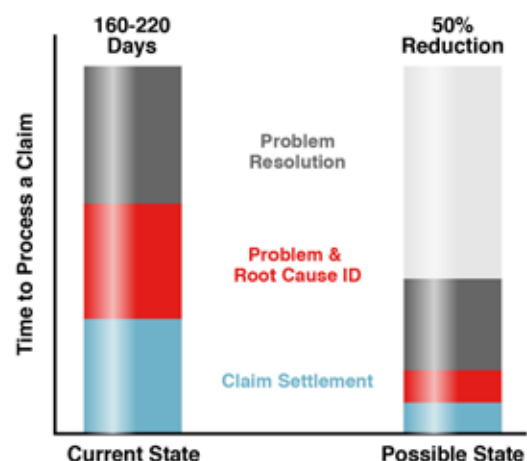
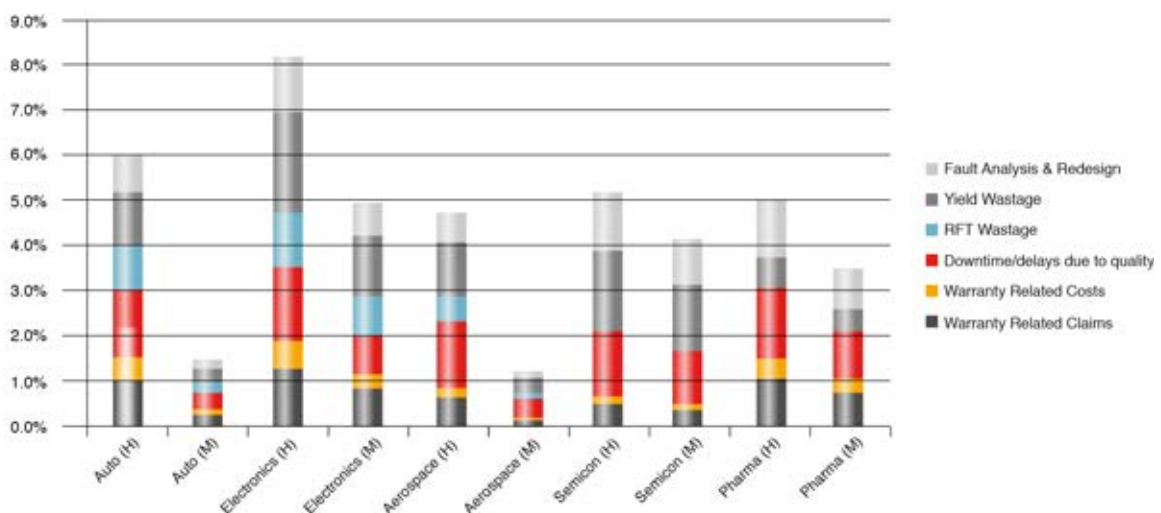


Figure 7: Potential Savings by Sector (Medium and High Case)

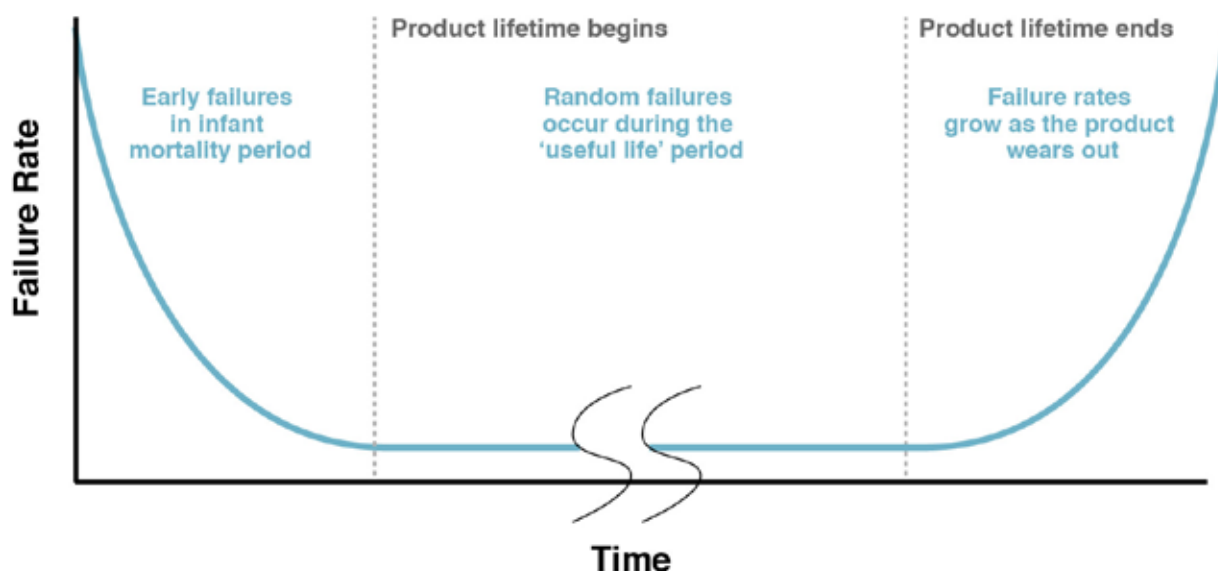


Better lifecycle costs & lower environmental impact

SigmaGuardian maximises the efficiency of plant or production line by locating the faults that slow processes down and create waste. Energy/utility bills and environmental impact can be reduced but most importantly production and quality levels are maintained whilst energy is optimised.

Advanced Analytics can also extend the lifecycle of a product as highlighted in Figure 8 below. The bathtub curve is a widely used term in reliability engineering and is derived from the cross-sectional shape of a bathtub. The bathtub curve is generated by mapping the rate of early “infant mortality” failures when a product is first introduced, the rate of random failures with constant failure rate during its “useful life”, and finally the rate of “wear out” failures as the product exceeds its design lifetime.

Figure 8: Using Advanced Analytics to extend the ‘bathtub curve’



Background

Motorola is not only one of the first and largest mobile telecoms manufacturers, it is also the originator of Six Sigma - the quality standard strived for by the majority of engineers worldwide.

Whilst they still widely implement Six Sigma techniques across their factories and processes, Motorola recently went one step further and utilised new technology developed by the academic co-founder of Warwick Analytics to solve a No Fault Found (NFF) issue and significantly reduce their Cost of Poor Quality (COPQ).

The issue

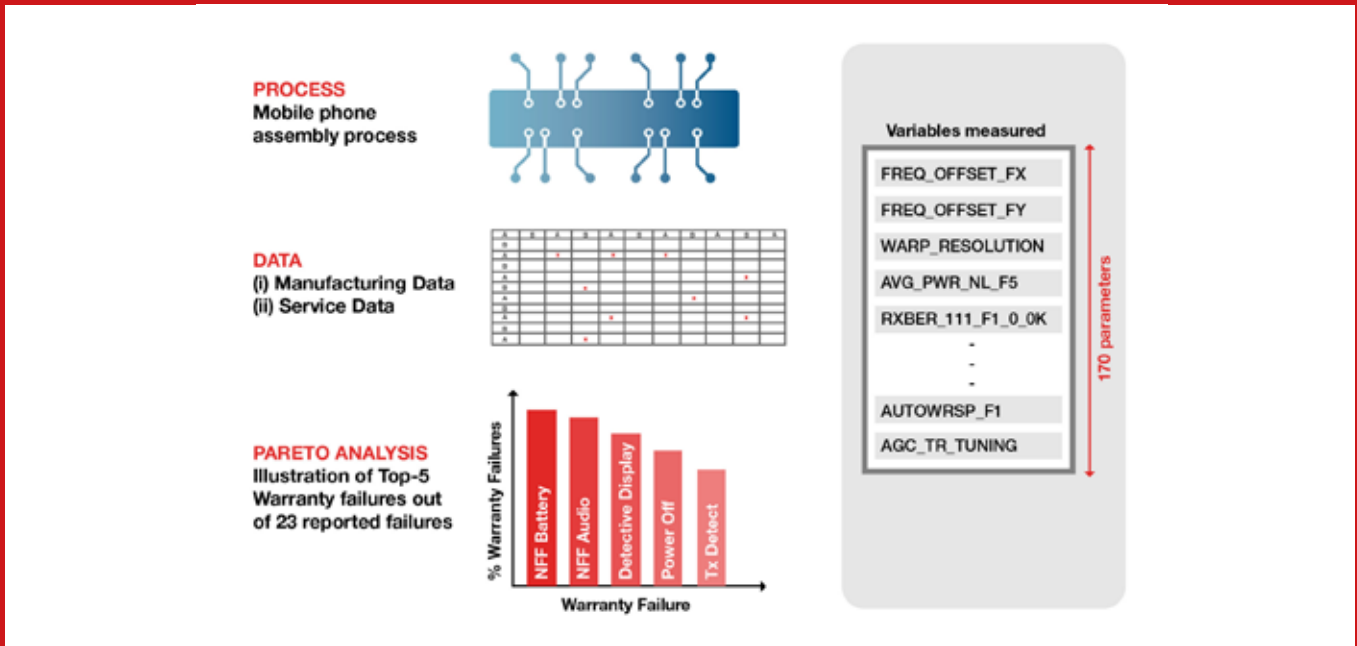
Two of the most prominent quality issues for a particular Motorola mobile phone model were NFF issues related to audio and battery. These issues were costing them a significant amount in terms of returns, replacements and reputation –the typical costs associated with COPQ.

The process

Data supplied by Motorola was analysed using the technology now known as Root Cause Analysis Solver Engine (RCASE), which form the core algorithms within SigmaGuardian, Warwick Analytics' Early Warning and Prevention system.

The data provided were warranty data that highlighted NFF issues and also End of Line (“EOL”) testing process data consisting of 170 parameters. Although reasonably comprehensive, the warranty data was incomplete and “dirty” thus making any statistical approach to resolving the root cause extremely challenging. Note that all of the 170 testing parameters were within tolerance, meaning that it was not possible to identify the root cause of the problem from this data alone.

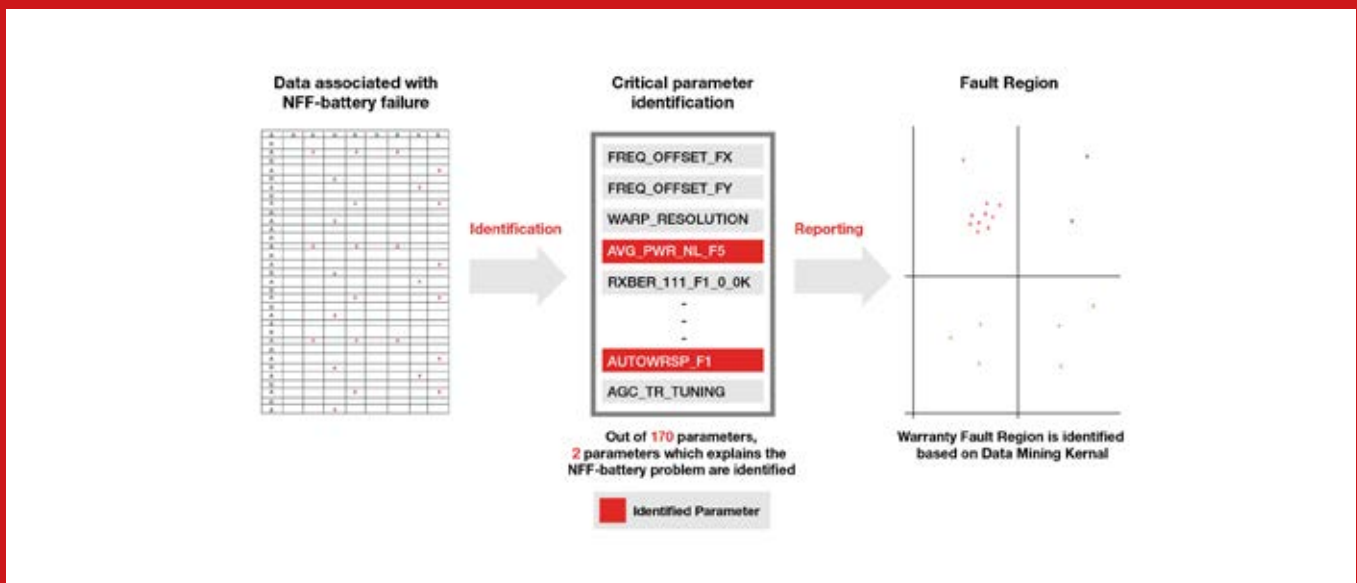
However, as RCASE is based on information theory and is ‘non-statistical’, it takes whatever data is available, whether dirty or incomplete. It does not rely on assumptions or setting up complex multivariate analyses. Even if the key parameters causing the issue are not present in the dataset, it will never give an incorrect answer, and it will still narrow the search space and advise where to look next. This is a different approach to statistical theories which try to find a best fit and can be skewed on incomplete datasets.



The solution

The results of the analysis picked out the key parameters which, albeit all individually within tolerance, were in combination contriving to cause the root cause of the issue. Furthermore, the ‘fault region’ was also quantified, meaning that it was possible for the manufacturing engineers to easily identify and predict when the failure would occur again. The faults could therefore be swiftly almost entirely eliminated by Motorola adjusting its Statistical Process Control to obviate the problem so that no latently faulty phones passed the EOL testing. The model of phones was also redesigned in the next generation to improve the yield inside the factory.

In conclusion, as a result of using RCASE, the NFF issues which were the top 2 warranty failures were no longer in the top 50 warranty failures.



CAPA

Corrective And Preventive Actions or Corrective Action/Preventative Action

COPQ

Cost of Poor Quality

ERP

Enterprise Resource Planning: system for managing resources and information

MES

Manufacturing Execution Systems: factory automation software

NFF

No Fault Found

OEM

Original Engine Manufacturer

PLM

Product Lifecycle Management

RCASE

Root Cause Analysis Solver Engine: Core algorithms within SigmaGuardian

SPC

Statistical Process Control

UI

User Interface: Graphical interface used by users to access software