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Semiconductor design for automotive: validation of new algorithms for test coverage estimation

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Context: statistics in design

- Design is typically addressed by schematic and layout software in which statistics may be not or rarely present.
- However, statistics appear in capability estimation: tricky calculations may be performed to take into account all the elementary standard deviations all along a signal path, to obtain the total distribution shape for the path.
- Statistics are also widely present when component working is simulated to estimate outputs: Monte-Carlo algorithms are used for that. Ellipse confidences are implemented for bivariate analysis.
- JMP Pro is always used to validate the algorithms on data set before implementation in the layout-dedicated software.

New topic

- A new topic just raised up now, about simulation of parametric, hard or soft defects: by these new studies, test coverage estimation is aimed: or failure rate estimation when occurrence probability is linked to defects. For test coverage or failure rate, issue is huge time needed to simulate all defects and their detection. So, purpose is to implement the best algorithm to reduce number of simulations, without impacting estimation precision: for this, JMP Pro provides interesting options in clustering or others. NXP experiments will result in an algorithm and in some recommendations for the new IEEE standard on study about defect coverage accounting method.

P2427 IEEE Standard: Analog Defect Modeling and Coverage

- This standard defines a defect coverage accounting method based on simulation models for defects observed within integrated circuits (ICs). The portion of all possible defects that are detected or “covered”, by tests of analog and mixed-signal circuits depends, in practice, on many factors … , which this standard considers as it defines how to report coverage.
- This standard focuses on defects in analog functions. In this context, “defect” is an unintended physical change in a circuit and an “analog function” means a function that has input, internal, or output signals with meaningful values in a defined continuous range, and the function has at least one parametric performance that is sufficiently non-deterministic that its test has upper and/or lower limits (the limits may be real numbers or quantized digital equivalents).

- Defect Model, Short: a Defect Model that adds a resistive connection between two nodes that were unconnected in the defect-free netlist.
- Defect Model, Open: a Defect Model that breaks a connection between two (or more) Circuit Elements of the defect-free netlist, creating an additional node.

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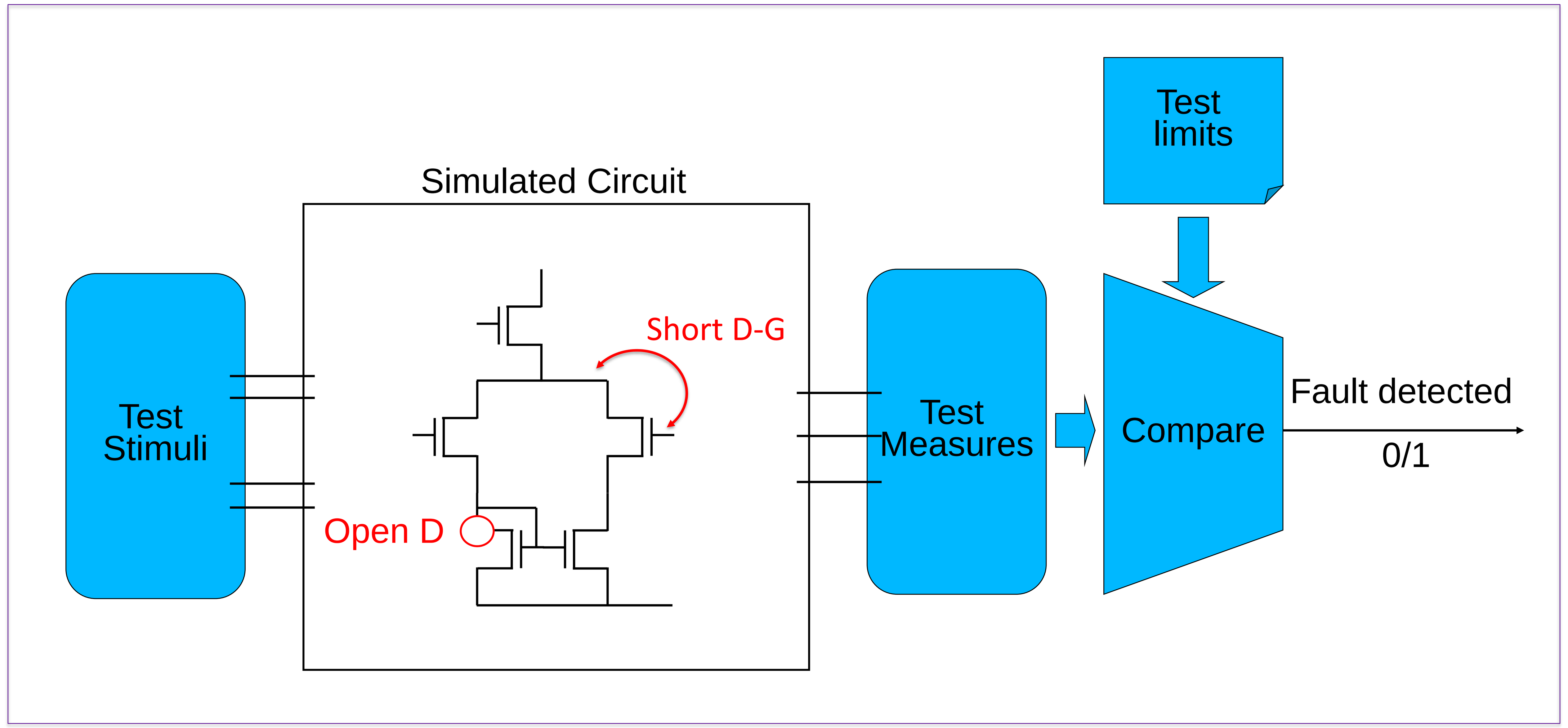
Iterative clustering by k-means method

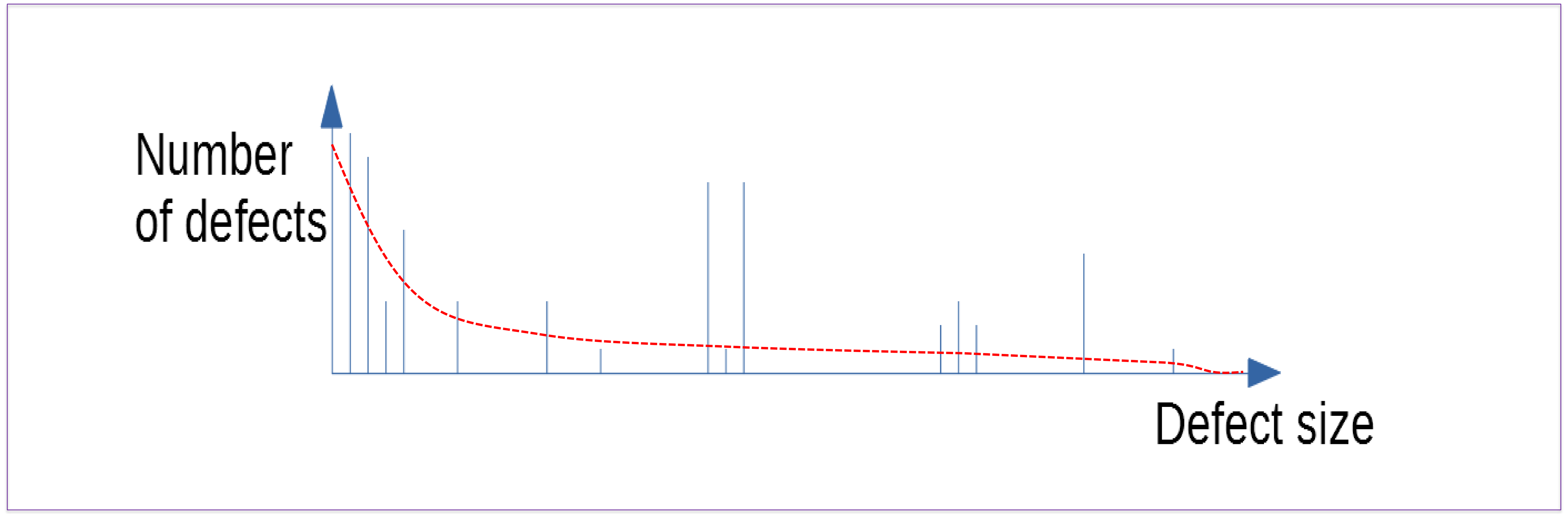
Problem statement

- An Analog defect may occur at each device and at each terminal of the device and at any terminal combination of the device.
- The number of potential defects rises fast with increasing design elements used and instantiated.
- Most of the defects need to be simulated to verify if the tester pattern can detect them. Structural Analyses may help in this study but not as much as needed. So, a large number of simulation need to be done to be able to create a defect test coverage.
- Question is; how can we reduce the number of simulations down to a usable number without sacrificing the result ?



Iterative clustering by k-means method

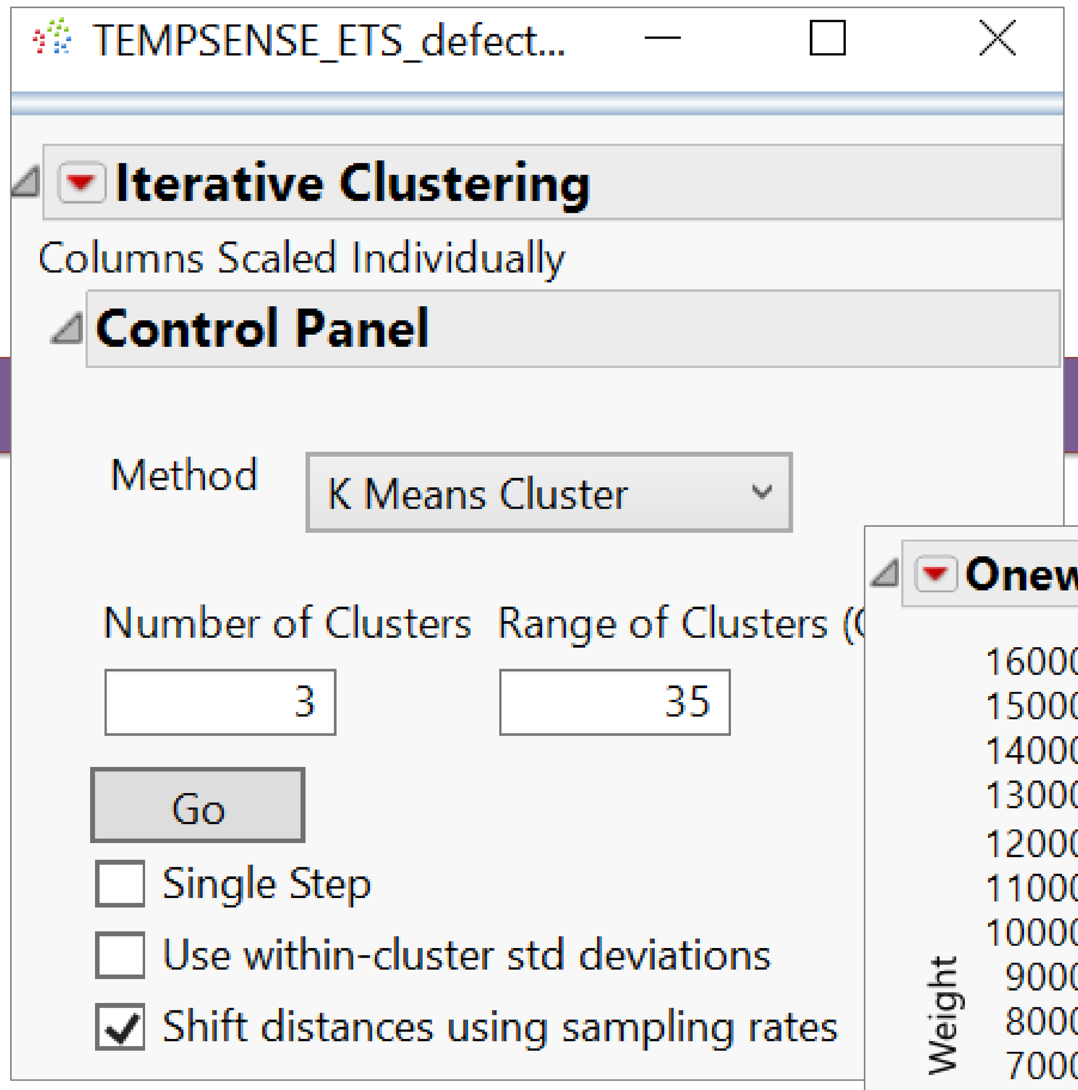
- A k-means method is implemented:
  - One dimension is weight for each defect, that is fitting with defect probability based on Silicon area (defect size);
  - A second dimension is artificially introduced containing no variability (constant): in case of ppm estimation, this second dimension could be used to take into account detection probability.
- The number of clusters is typically equal to 30. Then, in each cluster, data are sampled and sampling rate is adjusted so that the final quantity of sampled defects is equal to 1000, which means about 30 defects per cluster; this number of 30 defects becomes a minimum. Furthermore, sampling rate is adjusted according to cluster weight: when, for a cluster, its weight is superior to 3.33% of total weight for the block that is wanted to be tested, sampling is increased, proportionally to weight percentage (60 samples for a cluster weight equal to 6.66%). Because of this minimum of 30 defects per cluster, when cluster weight is 2%, sample will contain 30 defects. And finally, when the cluster contains only 2 defects, all the 2 are selected to be simulated.
- Finally, this k-mean clustering approach and this sampling method associated provide a valid method to describe the defect distributions observed (some dominating samples with high size and plenty with lower height).



How to do in JMP PRO ?

Method test and validation

- k-means method is launched on 3 analog blocks inside an analog semiconductor: each block has a quantity of defects between 5 000 and 100 000. Validation is performed by non-parametric tests (Van der Waerden Test) to compare the initial defect distribution by their weight to the final distribution of clustered then sampled tests.



Available options studied

- Three options are possible with jmp for an iterative clustering with k-means method, and each one is studied in order to optimize the method that will be set in the design layout-dedicated tools:
  - Use or not within-cluster std deviations;
  - Shift distances using sampling rate;
  - Step by step.

The 'step by step' option is interesting since simulation time can be also impacted by the number of steps set to cluster the data.

In JMP, there is also a fourth option that is fitting with the possibility to set the number of clusters or to run the analysis for a range of this cluster number.

Finally, JMP provides an analysis to compare the different clustering and to highlight the best configuration in term of clustering method parameters.

- Use within-cluster std deviations

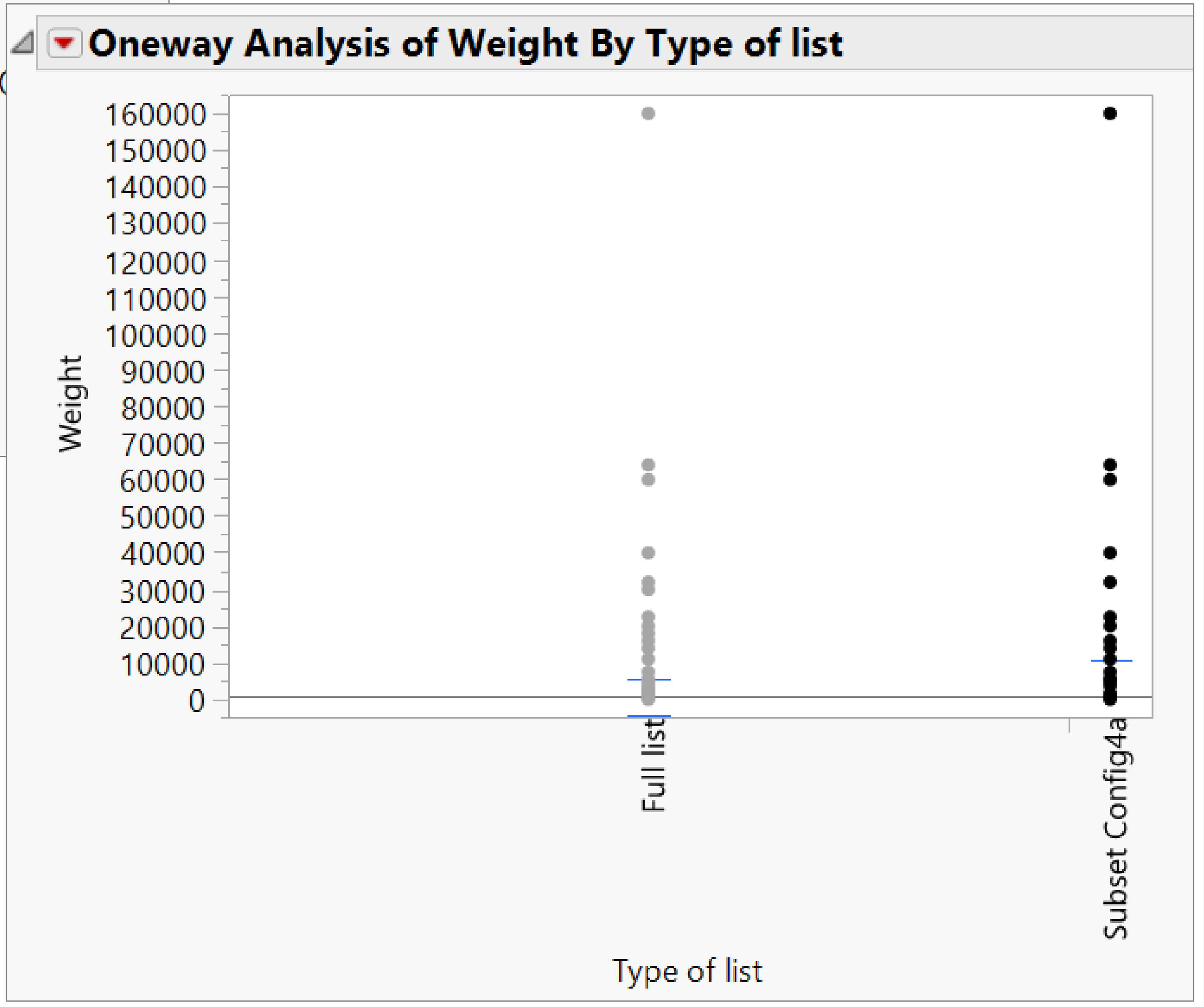
Scales distances using the estimated standard deviation of each variable for observations within each cluster. If this option is not selected, distances are scaled by an overall estimate of the standard deviation of each variable.

- Shift distances using sampling rates

Adjusts distances based on the sizes of clusters. If clusters are unequally sized, an observation should have a higher probability of being assigned to larger clusters because there is a higher prior probability that the observation comes from a larger cluster.

- Cluster Comparison Report

The Cluster Comparison report gives fit statistics to compare the various models. The fit statistic is the Cubic Clustering Criterion (CCC). Larger values of CCC indicate better fit. The best fit is indicated with the designation Optimal CCC in a column called Best. Constant columns are not included in the CCC calculation.



Van der Waerden Test (Normal Quantiles)

Level	Count	Score Sum	Expected Score	Score Mean	(Mean-Mean0)/Std0
Full list	4241	2,867	0,000	0,00068	0,155
Subset Config4a	425	-2,867	0,000	-0,00675	-0,155

2-Sample Test, Normal Approximation

S	Z	Prob>|Z|
-2,866805	-0,15535	0,8765

1-Way Test, ChiSquare Approximation

ChiSquare	DF	Prob>ChiSq
0,0241	1	0,8765

Conclusion

- From the tests performed with JMP on defect lists for analog components, it was possible to program and to implement the final method in the design tools, in the design-dedicated programming language. In this case study, as in many other cases JMP is used with strong benefits for its friendly interfaces and its different available configurations and options, to run quickly a statistical complex method.

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Semiconductor test for automotive: assessment and quantification of shift from normal distribution

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Introduction _ Problem Statement

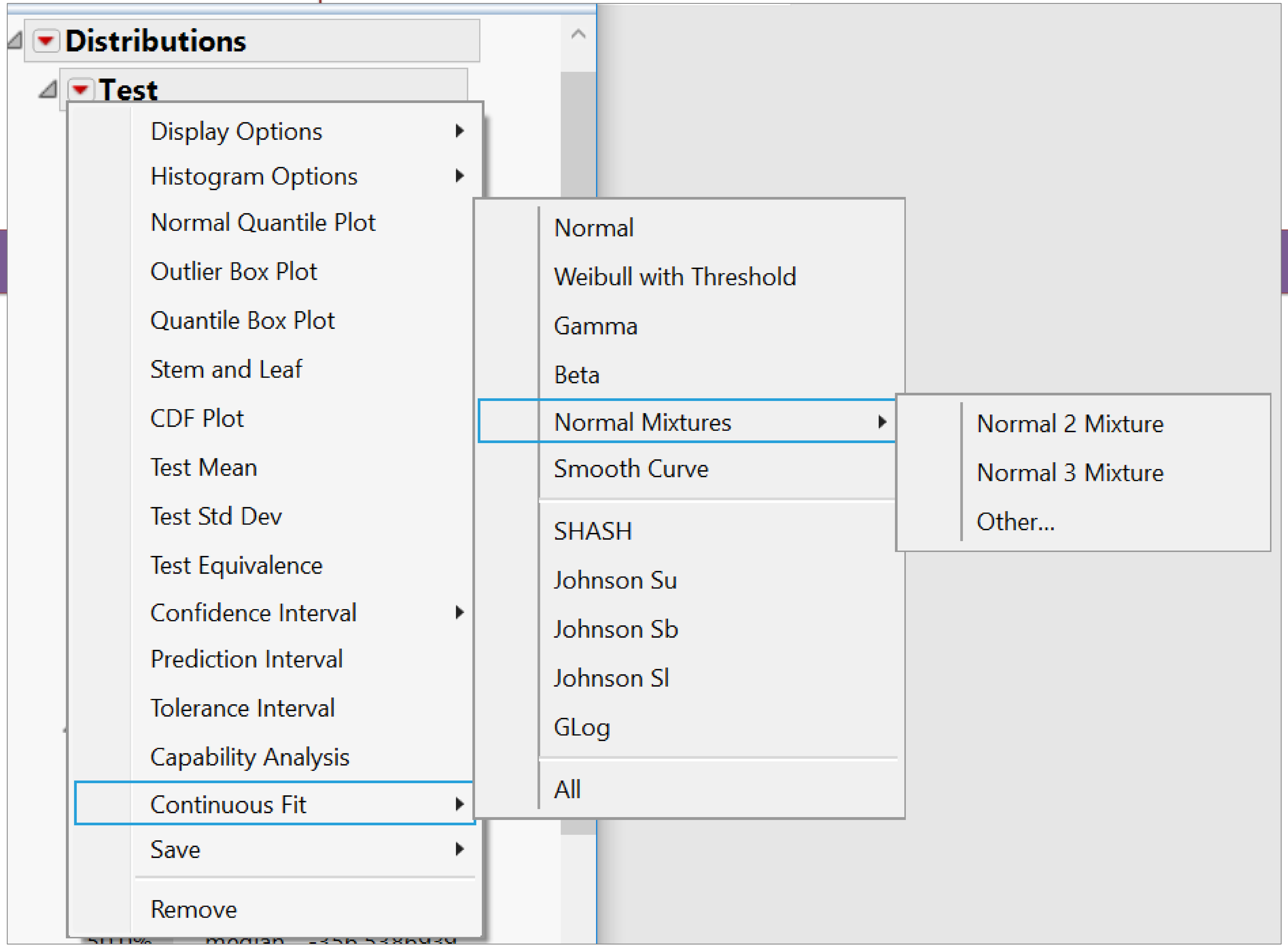
- Whatever the industrial context, all is based on the typical normal distribution: capability indices picturing manufacturing quality, or methodologies to detect and to screen outliers fitting with likely-to-fail parts, are designed from normal model.
- Preliminary step performed on manufacturing test results is to test normality. Most often the time, a small abnormality doesn't jeopardize capability index estimation or screening method implementation, even it is detected.
- Issue comes when normality test highlights abnormality for a majority of the 3000 wafer or final tests for an automotive semiconductor. Because of this great number of tests, a visual data set inspection is no longer possible.

Methodology: highlights

- In order to automatically quantify shift from normal distribution, a new methodology was studied from the SHASH distribution: from any data set, a SHASH model extracts normal parameters, mean and standard deviation, but estimates also kurtosis and skewness. Thus, it becomes possible to set a numerical threshold before which test distribution is considered normal even with a small abnormality or beyond which any method for normal distribution is no longer usable. And it becomes easy to run it on 3000 tests or more in some mouse clicks.
- With SHASH model, distribution platform and easy fitting option, JMP Pro allowed this.

Additional test distributions screened

- Issues in tester configurations or measure offsets may generate mixture of 2 or even 3 normal test distributions. It is important to detect them, in order to look for the root causes, to solve them and to come back to normal distributions. The new methodology described here, is designed to reveals these normal mixtures, too.



Methodology steps

- Method is run on all the tests that a semiconductor is subjected to, through several steps: the first one is fitting with a normality test implemented with a typical Lilliefors statistics.
- If this statistics detects the test as abnormal, then the heart of the method starts by a continuous fitting with three types of distributions: SHASH, mixture of 2 normal distributions and mixture of 3 normal distributions. This second continuous fitting step is linked to the selection of the model that provides the best fitting on data, shown by a minimum value for the corrected Akaike's Information Criterion. An exception is set when a mixture of 3 normal distributions is highlighted while the parameters for the third distribution are null (in this case, the distribution test will be handled as if it was a mixture of 2 normal distributions.
- Finally, a third step will consider some conditions based on the best model parameters that will definitively state about the test to flag it at risk or not, in term of reject.

SHASH distribution

SHASH distribution

- The SHASH distribution is also known as the sinh-arcsinh distribution. This distribution is similar to Johnson distributions in that it is a transformation to normality, but the SHASH distribution includes the normal distribution as a special case. This distribution can be symmetric or asymmetric.

SHASH distribution pdf:

$f(x) = \frac{\delta \cosh(w)}{\sqrt{\sigma^2+(x-\theta)^2}} \Phi[\sinh(w)]$ for -∞ < γ, x, θ < ∞; 0 < δ, σ

where:
Φ(.) is the standard normal pdf

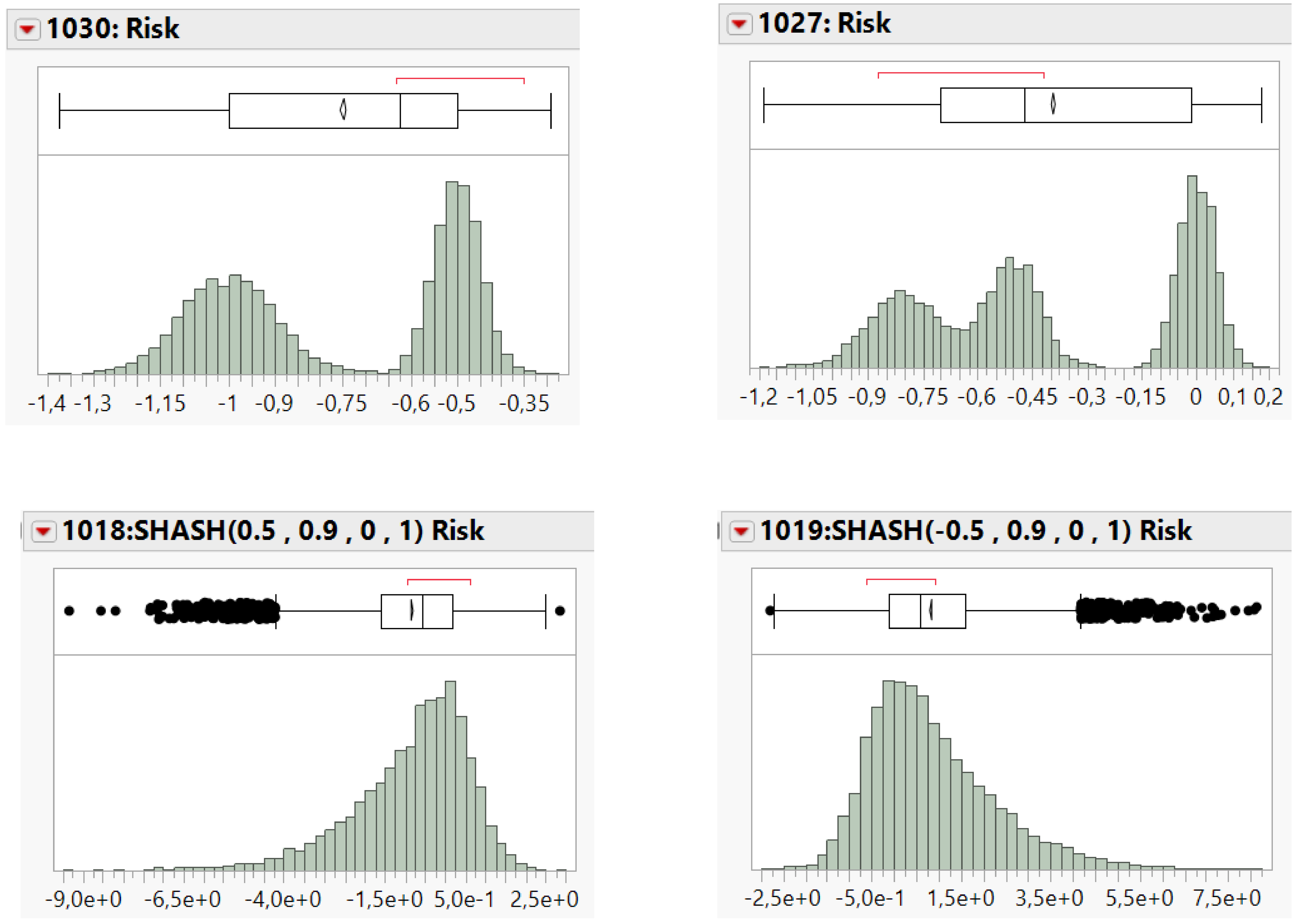
$w = \gamma + \delta \, sinh^{-1}\left(\frac{x-\theta}{\sigma}\right)$

When γ = 0 and δ = 1, the SHASH distribution is equivalent to the normal distribution with location θ and scale σ.

Test sorting criteria

- Distribution is at risk regarding rejects screening if :
  - For ‘Normal 2 Mixtures’ or ‘Normal 3 Mixtures’, with Mean1 < Mean2 < Mean3: Mean1+(n*stddev1) < Mean2-(n*stddev2) or Mean2+(n*stddev2) < Mean3-(n*stddev3) (n is typically equal to 3)
  - For SHASH: (gamma >0.4 or gamma <-0.4) and delta < 1
- It is interesting to note that any distribution, fully different than a normal one, a SHASH one or a normal mixture will be flagged at risk, and will generate actions from engineers to understand the real model for the test, but above all the factors leading to the type of distribution and to be corrected.

4 test distributions flagged as risky:



(gamma, delta, theta, sigma) = (0.5, 0.9, 0, 1)

(gamma, delta, theta, sigma) = (-0.5, 0.9, 0, 1)

Automation with a JMP script

JMP script

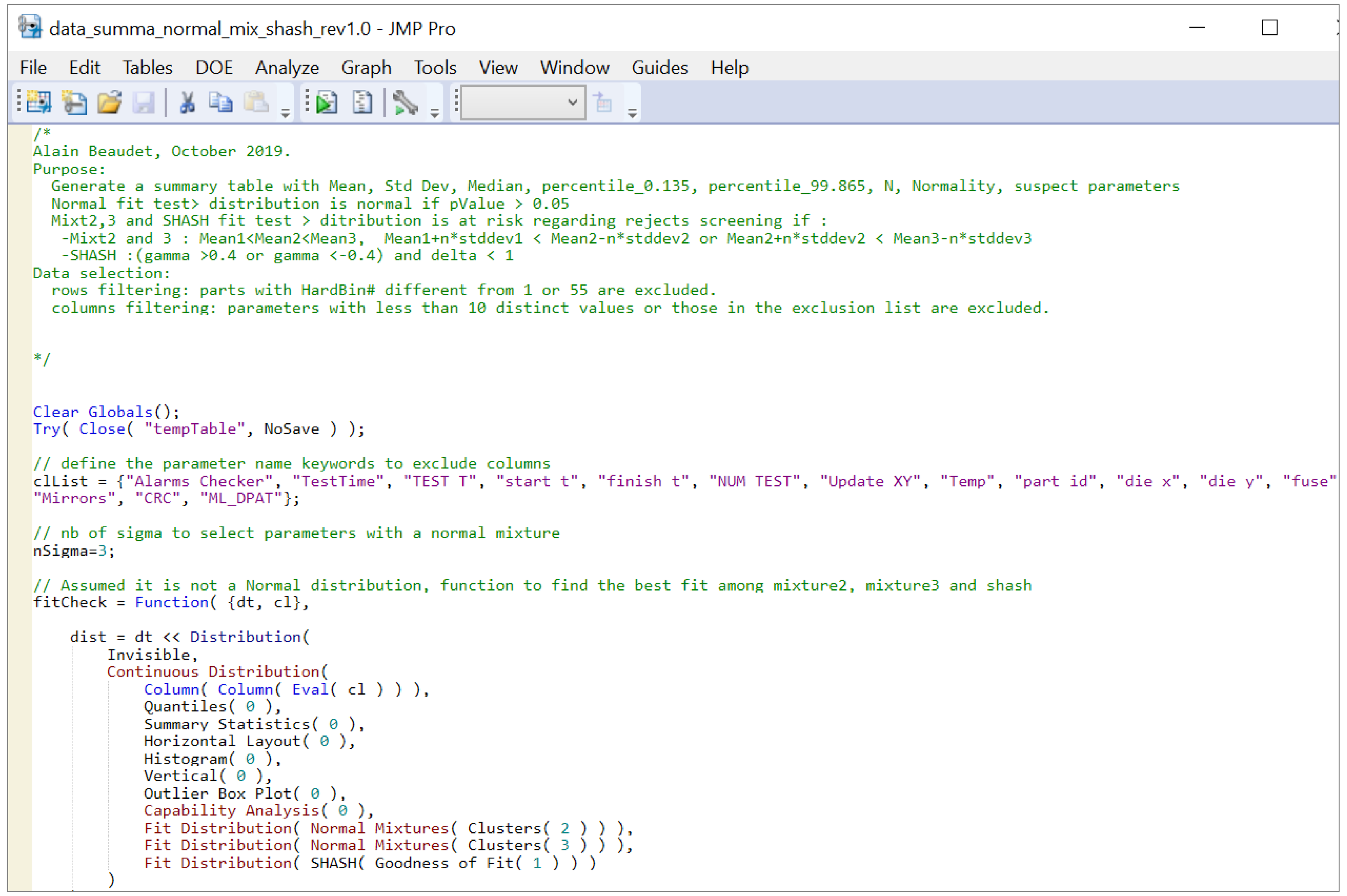
- A full automation is implemented via a script that runs the three methodology steps. Input for this script is the result of the all the tests for wafer or assembly lots. Script output is fitting with a table of the tests in which the tests at risk are highlighted: parameters of the models with the best fitting are reported to. The jmp script plots also histograms for these risky tests: so, visualization is highly facilitated for the engineers dedicated to study this real abnormality.

JMP script test and validation

- Two methods to test the script are used.
- The first one starts by generating different typical distributions, using the random formula in JMP (Normal, SHASH, Normal 2/3 mixtures, SHASH), and changing parameters of the randomly generated distributions. The script has to detect the distributions with the generated model, and flag it or not, according to the set parameters.
- The second one is with a data set from real tests: this second way of work allows to adjust the criteria, according to engineers' expertise.

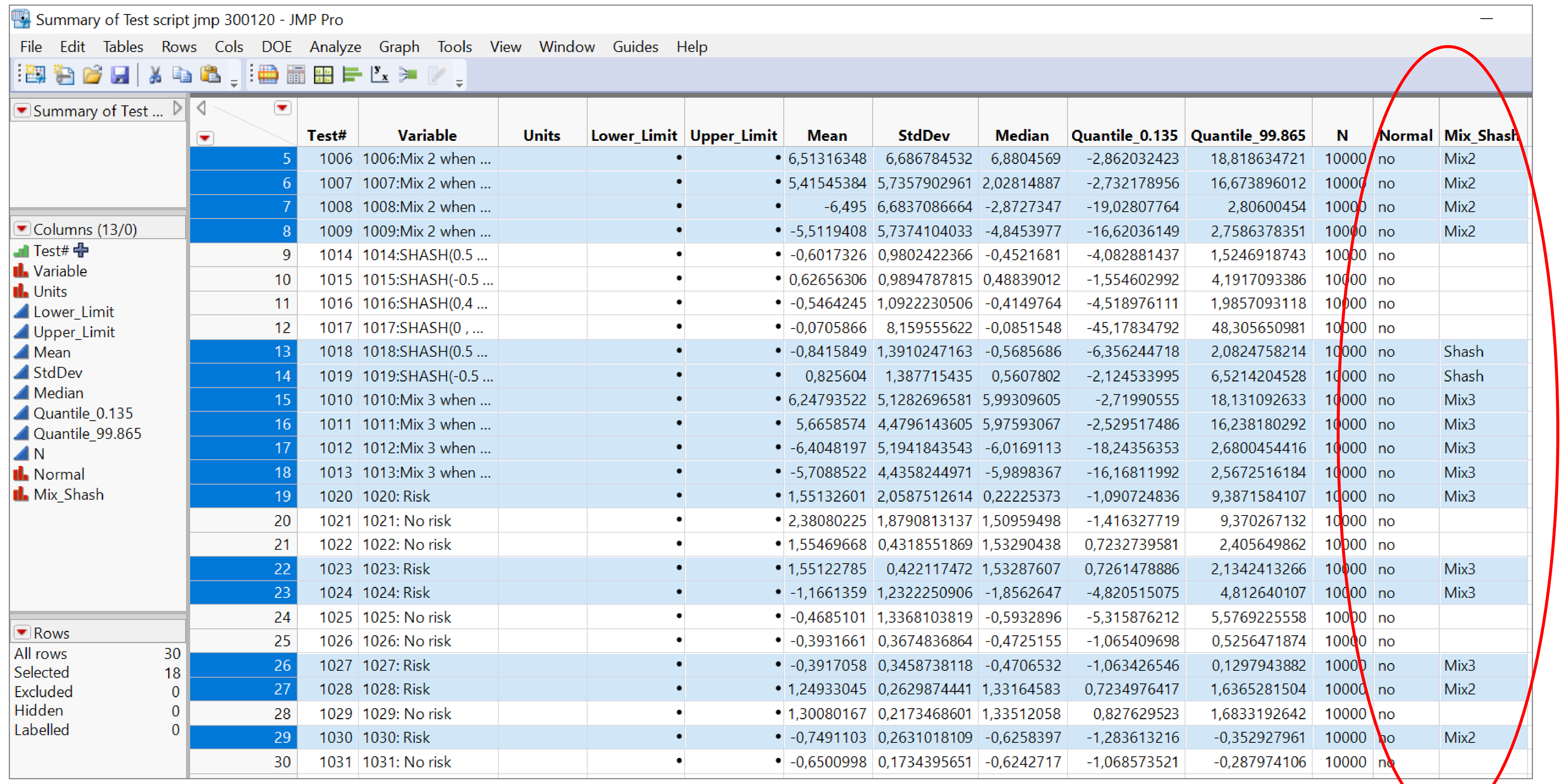
Conclusion and next steps

- A significant benefit is obtained by this little script, for the engineers in charge of a product and of its test results in wafer fab or final test. Normality is commonly used in many screening tests and when normality is not checked, it is important to quantify this abnormality, to model the observed distribution and to understand the abnormality root causes. Which is maybe possible when it deals with some tests, is no longer possible when hundreds of tests are abnormal. Automating the check for normality and the search for the fitting model, this script makes possible engineers' work on the abnormal tests. Thus, engineers will be able to challenge component design that may induce the abnormality, to correct some wrong tester settings, and to perform the missing gage study, all these three points being able to shift distributions to abnormality.



data_summa_normal_mix_shash_rev1.0 - JMP Pro

```
/*
Alain Beaudet, October 2019.
Purpose:
  Generate a summary table with Mean, Std Dev, Median, percentile_0.135, percentile_99.865, N, Normality, suspect parameters
  Normal fit test> distribution is normal if pValue > 0.05
  Mixt2,3 and SHASH fit test > ditribution is at risk regarding rejects screening if :
   -Mixt2 and 3 : Mean1<Mean2<Mean3,  Mean1+n*stddev1 < Mean2-n*stddev2 or Mean2+n*stddev2 < Mean3-n*stddev3
   -SHASH :(gamma >0.4 or gamma <-0.4) and delta < 1
Data selection:
  rows filtering: parts with HardBin# different from 1 or 55 are excluded.
  columns filtering: parameters with less than 10 distinct values or those in the exclusion list are excluded.


*/


Clear Globals();
Try( Close( "tempTable", NoSave ) );

// define the parameter name keywords to exclude columns
clList = {"Alarms Checker", "TestTime", "TEST T", "start t", "finish t", "NUM TEST", "Update XY", "Temp", "part id", "die x", "die y", "fuse"
"Mirrors", "CRC", "ML_DPAT"};

// nb of sigma to select parameters with a normal mixture
nSigma=3;

// Assumed it is not a Normal distribution, function to find the best fit among mixture2, mixture3 and shash
fitCheck = Function( {dt, cl},

    dist = dt << Distribution(
        Invisible,
        Continuous Distribution(
            Column( Column( Eval( cl ) ) ),
            Quantiles( 0 ),
            Summary Statistics( 0 ),
            Horizontal Layout( 0 ),
            Histogram( 0 ),
            Vertical( 0 ),
            Outlier Box Plot( 0 ),
            Capability Analysis( 0 ),
            Fit Distribution( Normal Mixtures( Clusters( 2 ) ) ),
            Fit Distribution( Normal Mixtures( Clusters( 3 ) ) ),
            Fit Distribution( SHASH( Goodness of Fit( 1 ) ) )
        )
```



Summary of Test script jmp 300120 - JMP Pro

	Test#	Variable	Units	Lower_Limit	Upper_Limit	Mean	StdDev	Median	Quantile_0.135	Quantile_99.865	N	Normal	Mix_Shash
5	1006	1006:Mix 2 when ...		•	•	6,51316348	6,686784532	6,8804569	-2,862032423	18,818634721	10000	no	Mix2
6	1007	1007:Mix 2 when ...		•	•	5,41545384	5,7357902961	2,02814887	-2,732178956	16,673896012	10000	no	Mix2
7	1008	1008:Mix 2 when ...		•	•	-6,495	6,6837086664	-2,8727347	-19,02807764	2,80600454	10000	no	Mix2
8	1009	1009:Mix 2 when ...		•	•	-5,5119408	5,7374104033	-4,8453977	-16,62036149	2,7586378351	10000	no	Mix2
9	1014	1014:SHASH(0.5 ...		•	•	-0,6017326	0,9802422366	-0,4521681	-4,082881437	1,5246918743	10000	no	
10	1015	1015:SHASH(-0.5 ...		•	•	0,62656306	0,9894787815	0,48839012	-1,554602992	4,1917093386	10000	no	
11	1016	1016:SHASH(0,4 ...		•	•	-0,5464245	1,0922230506	-0,4149764	-4,518976111	1,9857093118	10000	no	
12	1017	1017:SHASH(0 , ...		•	•	-0,0705866	8,159555622	-0,0851548	-45,17834792	48,305650981	10000	no	
13	1018	1018:SHASH(0.5 ...		•	•	-0,8415849	1,3910247163	-0,5685686	-6,356244718	2,0824758214	10000	no	Shash
14	1019	1019:SHASH(-0.5 ...		•	•	0,825604	1,387715435	0,5607802	-2,124533995	6,5214204528	10000	no	Shash
15	1010	1010:Mix 3 when ...		•	•	6,24793522	5,1282696581	5,99309605	-2,71990555	18,131092633	10000	no	Mix3
16	1011	1011:Mix 3 when ...		•	•	5,6658574	4,4796143605	5,97593067	-2,529517486	16,238180292	10000	no	Mix3
17	1012	1012:Mix 3 when ...		•	•	-6,4048197	5,1941843543	-6,0169113	-18,24356353	2,6800454416	10000	no	Mix3
18	1013	1013:Mix 3 when ...		•	•	-5,7088522	4,4358244971	-5,9898367	-16,16811992	2,5672516184	10000	no	Mix3
19	1020	1020: Risk		•	•	1,55132601	2,0587512614	0,22225373	-1,090724836	9,3871584107	10000	no	Mix3
20	1021	1021: No risk		•	•	2,38080225	1,8790813137	1,50959498	-1,416327719	9,370267132	10000	no	
21	1022	1022: No risk		•	•	1,55469668	0,4318551869	1,53290438	0,7232739581	2,405649862	10000	no	
22	1023	1023: Risk		•	•	1,55122785	0,422117472	1,53287607	0,7261478886	2,1342413266	10000	no	Mix3
23	1024	1024: Risk		•	•	-1,1661359	1,2322250906	-1,8562647	-4,820515075	4,812640107	10000	no	Mix3
24	1025	1025: No risk		•	•	-0,4685101	1,3368103819	-0,5932896	-5,315876212	5,5769225558	10000	no	
25	1026	1026: No risk		•	•	-0,3931661	0,3674836864	-0,4725155	-1,065409698	0,5256471874	10000	no	
26	1027	1027: Risk		•	•	-0,3917058	0,3458738118	-0,4706532	-1,063426546	0,1297943882	10000	no	Mix3
27	1028	1028: Risk		•	•	1,24933045	0,2629874441	1,33164583	0,7234976417	1,6365281504	10000	no	Mix2
28	1029	1029: No risk		•	•	1,30080167	0,2173468601	1,33512058	0,827629523	1,6833192642	10000	no	
29	1030	1030: Risk		•	•	-0,7491103	0,2631018109	-0,6258397	-1,283613216	-0,352927961	10000	no	Mix2
30	1031	1031: No risk		•	•	-0,6500998	0,1734395651	-0,6242717	-1,068573521	-0,287974106	10000	no	

Columns (13/0): Test#, Variable, Units, Lower_Limit, Upper_Limit, Mean, StdDev, Median, Quantile_0.135, Quantile_99.865, N, Normal, Mix_Shash

Rows	
All rows	30
Selected	18
Excluded	0
Hidden	0
Labelled	0

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NXP Structured Problem Solving: data analysis, visualization and search for evidences with JMP Pro

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Abstract

- Structured Problem Solving is one of the three pillars of NXP Six Sigma system, with Quality Culture and Continuous Improvement, and demonstrates still more NXP Quality system maturity.
- The typical DMAIC used in a continuous improvement project is improved to focus root cause elimination, and becomes the e-DMAIC template (e for elimination mindset).
- Besides the e-DMAIC used in a continuous improvement project, some key tools used by NXP in its SPS approach are 8D and 5-Why frameworks.
- About the second one, NXP significantly improved it, introducing three topics in the 5-Whys (failure occurrence, and two types of escape), and addressing technical and systemic root causes. This innovative 3 x 5 Why template is governed at NXP corporate level, meaning that each critical issue that NXP may face, goes through it.
- Statistics are highly involved in Structured Problem Solving, in a e-DMAIC framework as in this specific 3 x 5 Why tool, in the fact that we are always looking for evidences, and evidences are provided by data and by their statistical management. Besides evidence, another key concept is visualization, for example with the A3 template to communicate about progress performed on a project and its volume of work associated, but also pareto charts, or any type of charts.
- All the statistical capabilities provided by JMP Pro, as modeling, DOE, multivariate analysis, are used in SPS, searching for evidence and data visualization.
- This poster presents NXP SPS approach, and the place reserved for statistics, typically computed with JMP.

What is Structured Problem Solving (SPS) in NXP today ?

- A component in a Six Sigma/Total Quality system
- A specific organization to formalize and to help its implementation
- SPS methodologies benchmarked (VDA, AIAG, IATF, Ford, Bosch, Toyota)
- SPS methods also assessed and implemented at NXP suppliers’
- Frameworks as 8D always more tooled, and particularly more statistically tooled
- An efficient root cause searching tool (3x5 Why template) with a world wide governance
- Continuously improved and updated methods (e-DMAIC, visualization, A3 reporting, new FMEA standard)
- Training available for everybody

The three pillars of NXP Six Sigma system

Quality culture, mindset →

Typical Six Sigma, with frameworks as DMAIC, DMADV →

Problem Solving with framework as 8D, and tools as 3x5 Whys →

Objective	Description
Business Transformation	A major shift in how the organization works; aka ‘culture change’. Examples: • Creating a customer-focused attitude • Building greater flexibility • Abandoning old structures or ways of doing business
Strategic Improvement	Targets key strategic or operational weaknesses or opportunities. Examples: • Speeding up product development • Enhancing supply chain efficiencies • Building e-commerce capabilities
Problem Solving	Fixes specific areas of high cost, rework or delays. Examples: • Shortening application processing time • Reducing parts shortages • Decreasing volume of past-due receivables

Quality tools and statistical methods: a classification …

Tools to work with ideas	Value Stream Mapping and Process Flow Tools	Voice of Customer	Data Collection	Descriptive Statistics and Data Displays	Variation Analysis	Identifying Causes	Verifying Causes / Conforming causal effects	Reducing Lead Time and Non-Value-Add Cost	Selecting and Testing Solutions
Brainstorming	SIPOC	VOC-VOB	Data collection planning	Measures of central tendency (mean, median, mode)	Run charts (time series plots)	Pareto Charts	Stratified data charts (multivari charts)	Lean	Benchmarking
Affinity diagrams	Top-Down Charting	Kano analysis	Measurement selection matrix	Measures of spread (range, variance, standard deviation)	Control charts	3x5 Whys	Statistical tests	Metrics of time efficiency	Solution selection matrix
Multivoting	Workflow diagram		Stratification factors	Boxplots	Process capability	Cause-and-Effect diagrams (Fishbone or Ishikawa	Scatter plots	Time traps vs capacity constraints	Cost evaluation
	Swim-lane flowchart		Operational definitions	Histogram (frequency plot)	Anova	Cause-and-Effect matrix	Confidence Intervals	5S	Impact/Effort matrix
	Value stream map		Checksheets	Normal distribution			Comparative methods	Pull Systems	Controls assessment matrix
	Value-add vs non-value-add analysis		Sampling	Non-normal distributions and the Central Limit			Correlation	Total Productive Maintenance (TPM)	Failure Modes and Effects Analysis
	Time value maps		Measurement System Analysis				Regression	Mistake proofing & prevention (Poka-yoke)	Pilot testing
	Task time or takt time chart		Gage R&R				ANOVA	Visual Process Controls	
							Design Of Experiments		

→ These tools are used in the 2 main types of activities:

NB: The boxes highlight methods that essentially involve statistics

- Continuous improvement

Six Sigma program more and more mature

- Structured problem solving

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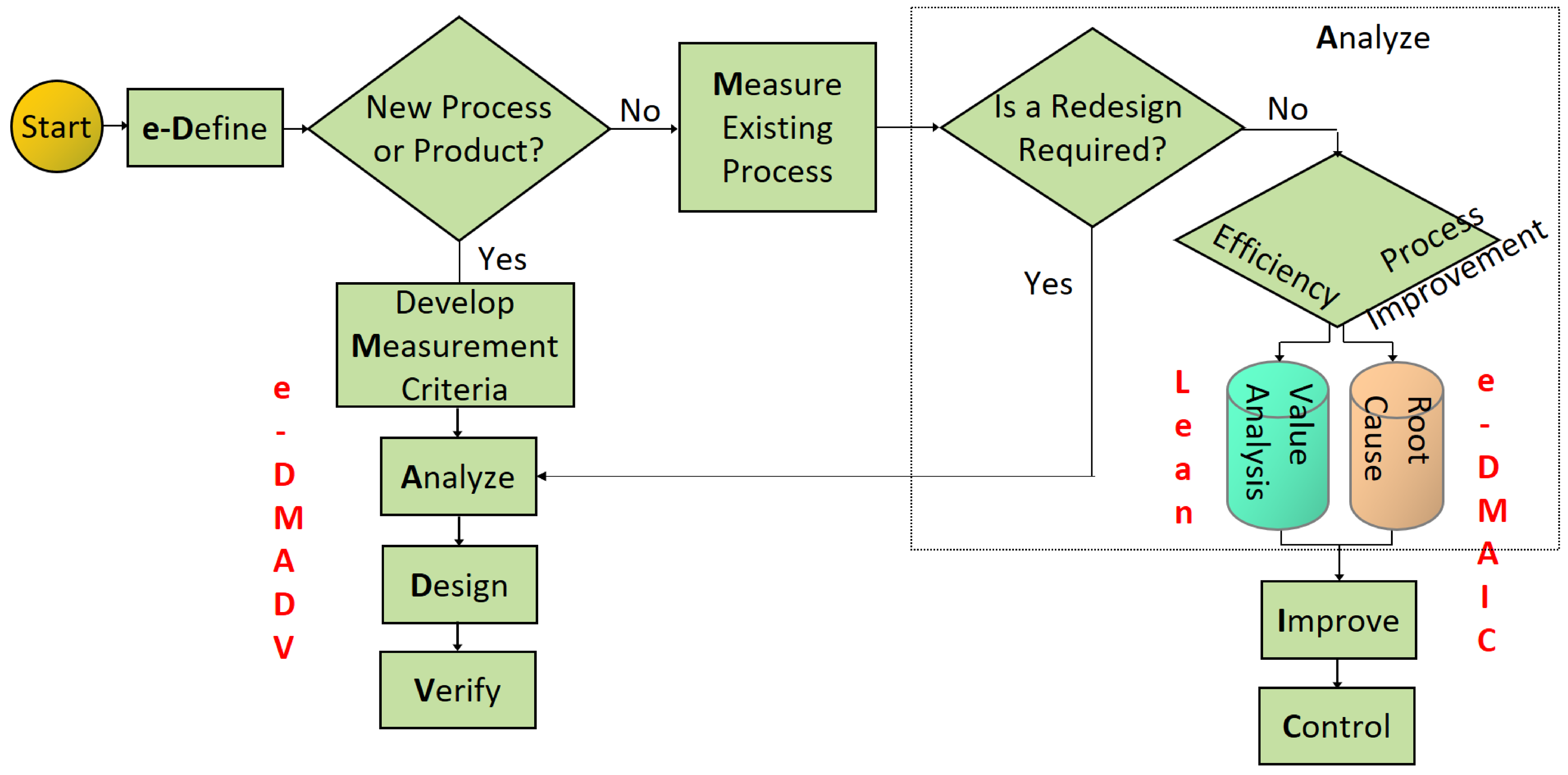
Six Sigma e-DMAIC approach

e-DMAIC flow diagram

- A key point or success factor in continuous improvement projects or SPS is a complete questioning in all the steps: if a question is missed, a solution may be also missed.
- Knowledge of the available tools is also important.
- These flow diagrams of the different stages may help to concatenate the questions and the answering and analysis methods potentially implementable.



DEFINITION

- Project definition tools
  - VOC/VOB (Voice of Customer/Voice of Business)
  - Kano
  - QFD (Quality Function Deployment)
  - Project Charter
- Process mapping tools
  - SIPOC (Supplier-Input-Process-Output-Customer)
  - Top-Down Charting
- Quick Wins

MEASURE

- Determine what to measure
  - Cause & Effect Diagram
  - Is/Is Not
- Manage measurement
  - Measurement Plan
  - Operational Definition
  - Basic Statistics
- Evaluate measurement systems
  - M.S.A. (Measurement System Analysis)
  - S.O.V. (Source Of Variation) study
  - Multi-Vari Analysis
  - Capability Analysis Cp, Cpk and ppm of baseline performance

ANALYSIS

- Identify potential root causes
  - Quantitative-Qualitative Data
  - Pareto Chart
  - FTA (Fault Tree Analysis)
  - 5 Why
  - 3x5 Why
  - Cause & Effect Matrix
- Confidence Intervals
- Comparative Methods (mean and variance)
- Develop root cause hypothesis

IMPROVE

- Generate solutions
  - Failure Mode and Effects Analysis (FMEA)
  - Simple Linear Regression
  - Design Of Experiments (DOE)
- Selection of the best solution
  - Affinity Diagram
  - Solution Selection Matrix
  - Solution Implementation Plan

CONTROL

- Control Plans
  - Statistical Process Control (SPC)
  - Control charts for continuous and attribute data
  - Business Control Plan

A3 template

A3 Report format should follow e-DMAIC outline

Define:
- Business Case
- Problem Statement
- Project Goal
- Measurable / Metric

Analyze:
- Theories
- Why-Why to root cause(s)
- Validated Root cause(s)

Measure:
- Measurement Capability
- SOV / Contribution pareto
- Objective(s) linked to Goal

Improve:
- Validated Solutions
- Scope of Implementation

Control:
- Updated measurable / Metric to Goal
- Lessons Learned
- Fan-out / Propagation

- The size of the box is proportional to the amount of time/effort in each phase. e-DMAIC focuses ~75% of the effort around deeply understanding the problem, and ~25% of the time/effort around implementing and validating solutions.
- All the 5 DMAIC steps implement statistical tools and methods

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8D framework and “3 x 5 Whys” tool

8D framework for SPS

- 1D Team
  - Are all roles determined?
- 2D Problem description
  - Is the problem clear and verified? — Is – Is Not
  - Logistic impact clear and Lot list available?
- 3D Containment — Genchi-Genbutsu (Total Quality)
  - Verification of customer being safeguarded?
  - Thorough risk assessment performed for delivered material?
- 4D Root Cause — Fishbone / Ishikawa — FTA
  - All possible root causes investigated?
  - Verification?
  - 3 times 5Why used?
- 5D Determine Corrective Actions
  - Possible corrective actions determined? (occurrence, detection, prediction)
  - Verification of the effectiveness?
- 6D Implement Corrective Actions — PDCA (Plan-Do-Check-Act)
  - Implementation date clear? First batch? (etc.)
  - Validation of effectiveness?
- 7D Prevent Re-Occurrence
  - Poka Yoke used? — Poka Yoke
  - Are FMEA’s and Control Plan updated?
  - Have the Risk Assessment and learning been shared with other NXP organizations?
- 8D Conclude and Congratulate
  - Conclusion
  - Sign off (Problem owner, General Manager)

Scope 5Why

“3 x 5 Whys” template

	Technical Root Causes		Systemic Root Causes
OCCUR	Why ? → Why ? → Why ? → Why ? → Why ?	Continue →	Why ? → Why ? → Why ? → Why ? → Why ?
	We get to the source of the problem		Correct weakness in our systems, process, design, and/or culture SYSTEMIC: *OCCUR*
ESCAPE Root Cause	Why ? → Why ? → Why ? → Why ? → Why ?	Continue →	Why ? → Why ? → Why ? → Why ? → Why ?
	We improve our effectiveness of catching the issue or defect at the point of creation		Correct weakness in our systems, process, design, and/or culture SYSTEMIC: *ESCAPE of Root Cause*
ESCAPE Failing Product	Why ? → Why ? → Why ? → Why ? → Why ?	Continue →	Why ? → Why ? → Why ? → Why ? → Why ?
	We improve our effectiveness of preventing bad product downstream		Correct weakness in our systems, process, design, and/or culture SYSTEMIC: *ESCAPE of Failing Product*

The key to success: search for evidences !

Data and data analysis may be a strong way to highlight evidences. Statistics handle data uncertainty and variability.