UNIVERSITI SAINS MALAYSIA

Laporan Akhir Projek Penyelidikan Jangka Pendek

Development and Application Of Intelligent Manufacturing Using Artificial Intelligence Methodology

By

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Intel Research Grant

Final Report

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Development and application of intelligent manufacturing systems using artificial intelligence methodology

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1. Background

1.1 Research Description

Most of the products need a number of production stages before reaching customers. The undetected faults (though within the control limit) happened to equipment may affect the quality of the products. Faults are usually caused by a number of factors and it is usually too late to detect them at the final production stage. This will lead to time loss on troubleshooting and lot-tracking stage by stage. On top of this, cost per product will increase, had these defects gone through a number of production stages.

The aim of the development of an intelligent Fault Detection System is to proactively reduce and predict the occurrence of defects, thus reducing the unplanned downtime of equipment, and schedules to perform Preventive Maintenance (PM) on the equipment can be derived from this prediction. By using multivariate statistical analysis on the input and output parameters and the study on the relationship among these parameters, the system may be able to predict the occurrence of defects and may feedback to engineers to perform troubleshooting on the current process and equipment. This could lead to better quality of the products.

This project examines the development of a predictor model, based on Multivariate Statistical Analysis over a range of data on the observed and controlled parameters for fault detection. It involves complicated variables, constraints and conditions to indicate the likelyhood of detecting the faults or defects.

1.2 Research Purpose

The purpose of the Fault Detection System is to create a generic system that will detect and predict quantitatively the defects from the input parameters. The impact and correlation of inputs variability will be studied and analyzed by using Multivariate Data Analysis. From the results of these analyses, the patterns of the defects will be captured. The system will be trained to recognize these patterns and issue an early warning to the operators.

It will serve to reduce or eliminate potential yield loss to predict if equipment will down and thus avoiding unnecessary reactive corrective actions, which might be caused by over-sensitivity. The system will monitor, interpret and visualize time-series and measurement data in real-time, giving the company controls over the process tool performance.

1.3 Research Justification

The Fault Detection System will be tested at SCAM. Current Die Side Capacitor Touchup (DSCT) rate is about 4%. The success of the system will help to reduce DSCT rate and potential yield loss deduction. The system will serve as a closed-loop feedback tracking system for each triggering, thus remove the human dependency in triggering the response and reduce the workload of operators. This would directly help to reduce the incidences of sudden lot pile-up at touchup station. There is a potential to eliminate PEVI operation through the deduction/control in DSCT. The success of the system could reduce the cost per product.

2. Parameters and Data

2.1 Parameters

Primary Input Parameters, Xs:

1. Capacitor Placement Offset – X (CPO-X)
2. Capacitor Placement Offset – Y (CPO-Y)
3. Solder Paste Offset – X (SPO-X)
4. Solder Paste Offset – Y (SPO-Y)
5. Solder Paste Volume – Average (SPV-Ave)
6. Solder Paste Volume – Standard Deviation (SPV-SD)

Secondary Input Parameters:

1. Substrate SLI #
2. Capacitor SLI #

Output Parameters, Ys:

1. DSCT Defects (together with lot's informations such as Date, Time, Quantity In...etc)

2.2 Data Availability

Source: Workstream

Period: from 7 January 2003 to 6 October 2003

The summary of total extracted data is in Table 12 and Figure 12.

2.3 Error in Extracted Data

After the data is extracted out from Workstream, data will be checked from the view of logic and correctness. The found errors are (Table 13):

1. Missing decimal point, such as 36840 instead of 3.6840 for CPO-X.
2. Data at the wrong column, such as SPO data at SPV column and vice versa.
3. Repeated data for CPO, SPO and SPV.

2.4 Software

Data Extraction:	EATS, customized program
Statistical Analysis:	JMP version 5.01

3. Data Analysis on Primary Parameters

3.0 Overall Plan of Data Analysis

For the path finding, 1 Output Parameter and 1 Product will be selected.

The Data Analysis (Figure 1) will be divided into 6 parts:

1. Select Output Parameter (Y)
2. Select Product
3. Select Machine
4. Univariate Analysis
5. Bivariate Analysis
    a. Correlationships between Output and Input Parameters (Xs)
    b. Correlationships between Input Parameters
6. Multivariate Analysis
    a. Partial Least Squares (PLS)
        i. Y and Xs are matched within ± 1 hour period
        ii. Y and Xs are matched within ± 1 day or a closer period
        iii. Y and (CPO–X, CPO–Y) are matched
        iv. Y and (SPO–X, SPO–Y, SPV-Ave, SPV-SD) are matched
    b. Clustering with Principle Component Analysis (PCA) using Fuzzy ARTMAP
        i. Y and Xs are matched within ± 1 hour period
        ii. Y and Xs are matched within ± 1 day or a closer period
        iii. Y and (CPO–X, CPO–Y) are matched
        iv. Y and (SPO–X, SPO–Y, SPV-Ave, SPV-SD) are matched

3.1 Select Output Parameter

The defects at DSCT are DSC Related, Peeled Termination, Misaligned Component, Excessive Solder, Missing Component, Damaged Component, Insufficient Component, Tombstone and Flipped Component.

From the extracted DSCT data, a Pareto Chart is plotted. (Figure 2)

Flipped Component, which will be called as DSC-Flipping at the later section, is selected as it is about 67% of all DSCT defects.

If we are to zoom down by machine level, Table 1 will be a good summary.

DSC-Flipping is the shifted DSC on the pad location of the substrate.

In this study, %DSC- Flipping = [Quantity_DSC-Flipping / IN_Quantity] X 100%.

3.2 Select Product

There are a number of products running at SCAM operation. They are Brookdale, Brookdale G, Canterwood, GCR, Gameboy, Montara, P64, Placer, Plumas, Springdale and others.

GCR is selected as target product as it is 39.60% of all products at SCAMs. (Figure 3 and Table 2)

3.3 Select Machine

There are 10 SCAM Machines, i.e. SCAM 01, 02, 03, ...10.

From Figure 4 and Table 2, we can summarized that SCAM 05, 08, 09 will be the target machines as more data is available to be used for analysis purpose.

However, in this data analysis, all SCAM Machines will be considered to serve as comparisons if the analysis is easy and not time-consumed to be done.

3.4 Univariate Analysis

In this and continuous section, GCR will be the product and Y is DSC-Flipping if it is not mentioned.

In this analysis, Mean and Standard Deviation, Median and Range will be calculated on Xs (CPO–X, CPO–Y, SPO–X, SPO–Y, SPV–Ave and SPO–SD).

The specifications of the Xs are:

CPO–X, CPO–Y	:	0±4.5 mils
SPO–X, SPO–Y	:	0±8 mils
SPV–Ave	:	5300±2100 mils^3
SPV–SD	:	No Specification.

From the summary in Table 3, over all SCAMs, the maximum mean for:

CPO-X = 2.043, CPO-Y = 1.928, SPO-X = 2.078, SPO-Y = 3.071, SPV-Ave = 4909.1.

By analyzing the distribution, there is no significant at the univariate analysis level.

3.5 Bivariate Analysis

From "Methods of Multivariate Analysis" by Rensher, Alvin C., the correlationships among 2 variables can be determined by calculating the correlationship ratio, r.

In this analysis, r will be calculated for:

a. Between Y and Xs

b. Between Xs themselves

From Table 4, for (a), at SCAM07, r between % Flip and SPV-Ave is 0.33, BUT with a small sample size, 91 compared to others. all coefficients are less than 0.50, which can be considered not significant to predict the % Flip.

As for (b), there 14 values of r are more than 0.50. However, these correlationships can be explained by measurement within same parameters, such as Capacitor Placement (CPO–X and CPO–Y), Solder Paste (SPO–X and SPO–Y). On top of this, the effect of small sample size is observed in these correlationships.

3.6 Multivariate Analysis

From the literature review, Partial Least Squares (PLS) is selected and Principle Component Analysis (PCA) is served as comparison.

Current practice of measurement for:

SPO and SPV – per set up (~every 6 hours)

CPO – per shift (~every 12 hours)

It is clear that the measurement timing for these parameters cannot be the same.

The limitation is "every lot which is passed through SCAM machines, is not tagged with these measurement data".

To start with multivariate analysis, it is a must to get the lot along with data from these 3 parameters, since PLS and PCA enquired a same matrix space for Y and Xs.

To gather more data for analysis, plans are set up based on matching with different parameters and periods.

2 methods will be used in this analysis:

a. Partial Least Squares (PLS)

b. Clustering with Principle Component Analysis (PCA) using Fuzzy ARTMAP

Since Xs only consist of SCAM ID and Date/Time, so pairing these data to the particular lot is needed. Both methods will use 4 type of data gathering:

i. Y and Xs are matched within ± 1 hour period

   Assumption: The keyed-in Date/Time of Xs data in Workstream within 1 hour comparing to the Date/Time of a particular lot. In another word, the performance of Capacitor Placement is consistent within the ± 1 hour when the measurement of Solder Paste is done.

ii. Y and Xs are matched within ± 1 day or a closer period

   Assumption: The performance of Capacitor Placement is consistent until the next measurement is done. This data will be paired with Solder Paste data at the closest period.

iii. Y and (CPO–X, CPO–Y) are matched

   Assumption: Capacitor Placement is the main contributor of DSC-Flipping.

iv. Y and (SPO–X, SPO–Y, SPV–Ave, SPV–SD) are matched

   Assumption: Solder Paste is the main contributor of DSC-Flipping.

However, from Table 5, data count in type (i) and (ii) are almost same. So, the data analysis will be treated as same for both types.

3.6.a Partial Least Squares (PLS) Analysis

Champagne, M. and M. Dudzic, [1] suggested batch process modeling with Partial Least Squares (PLS) method can be used in fault detection. In [2], [3], [4], [5] and [8], PLS method is used recently to solve the process monitoring system. But the data must be in batch. Data which is in batch along with Xs, will be counted to monitor the representation of the population (DSCT data).

The PLS Model ([6], [7], [9]) is a straight line equation, $\mathbf{Y} = \sum a_i X_i + C$, where i=1,2,3,4...n. For:

i. Y and Xs are matched within ± 1 hour period

ii. Y and Xs are matched within ± 1 day or a closer period

"$Y = aX_1+bX_2+cX_3+dX_4+eX_5+fX_6+C$", where

Y = % DSC-Flipping,

X_1=CPO–X, X_2=CPO–Y, X_3=SPO–X, X_4=SPO–Y, X_5=SPV–Ave, X_6=SPV–SD, C = Intercept.

iii. Y and (CPO–X, CPO–Y) are matched

"$Y = aX_1+bX_2+ C$", where

Y = % DSC-Flipping,

X_1=CPO–X, X_2=CPO–Y, C = Intercept.

iv. Y and (SPO–X, SPO–Y, SPV–Ave, SPV–SD) are matched

"$Y = aX_1+bX_2+cX_3+dX_4+C$", where

Y = % DSC-Flipping,

X_1=SPO–X, X_2=SPO–Y, X_3=SPV–Ave, X_4=SPV–SD, C = Intercept.

From Table 6, all coefficients (except C) are less than 0.50, which can be considered not significant to predict Y, %DSC-Flipping.

3.6.b Clustering with Principle Component Analysis (PCA) using Fuzzy ARTMAP

One of the popular and traditional methods for multivariate analysis is PCA ([10]). This method will transform the data into principle components.

More often they are obtained for use as input to another analysis, in this case, clustering. We can plot out the first 3 principle components in 3D Scatter Plots. However, visually justify the patterns of clustering is not good enough for this kind of quantitative analysis.

Fuzzy ARTMAP (Figure 5) is a supervised network, which means we need to divide our sample into 2 sets, training set (about 2/3 of sample size) and testing set (the remaining data). This model will then predict the output with the value of first 3 principle components from the balance of data. The predicted output will be compared to the actual output to check for the accuracy of prediction.

% DSC-Flipping (output) will cluster into few classes by determining the range.

SCAM09 is chosen as the sample size is the largest, 120, among all SCAMs.

Since training and predicting need a number of data, training set will be about 80 data, testing set is 40. The selection is based on random function.

We will try out 2 clustering based on %DSC-Flipping, 8 classes and 5 classes.

The classification results will show the accuracy of the training model when it is tested with testing set. Then average will be calculated from the accuracy results in all classes

i. Y and Xs are matched within ± 1 hour period

ii. Y and Xs are matched within ± 1 day or a closer period

Figure 6 is the 3D Scatter Plot on first 3 Principle Components. As we can observed from the plot is the points are scattering around, may not detected any centralized points.

In Table 7, we can see that the accuracy for both 5 and 8 classes are well below 50%.

iii. Y and (CPO–X, CPO–Y) are matched

Same conclusions are derived in Figure 7 and Table 8.

iv. Y and (SPO–X, SPO–Y, SPV–Ave, SPV–SD) are matched

Same conclusions are derived in Figure 8 and Table 9.

4. Data Analysis on Secondary Parameters

4.0 Overall Plan of Data Analysis

The Data Analysis (Figure 9) is very simple since the early parts have been done in previous section.

Every lot which processed through SCAM machines will be tagged along with Substrate SLI# and Capacitor SLI#. From these SLI #s, we can segregate the lots by suppliers.

In terms of amount of data, the analysis will have advantages over the previous analysis as the sample size is approximately same as the population.

4.1 Select Output Parameter, Product, Machine

Data will be the same batch as in Section 3.

Output Parameter will remain the same, i.e. %DSC-Flipping.

The Secondary Input Parameters will be the Substrate Suppliers and Capacitor Suppliers.

Product will still be GCR.

However, this analysis will cover SCAM 01 to SCAM 10.

4.2 Data Analysis

Some missing data are observed. At the early stage of implementation, SLI# is not compulsory to key into Workstream. These data are deleted.

AVX is no longer capacitor supplier to Intel.

The analysis is concentrated on current major suppliers, like Murata, TDK for capacitor and Ibiden, Samsung, Shinko, Nan Ya for substrate.

From the plots (Figure 10, Figure 11) and summary (Table 10), it is clear that particular substrate supplier, Ibiden (Japan and Philippines) with both current capacitor suppliers (Murata, TDK) is giving a higher % Flip compared to others like Samsung, Nan Ya and Shinko. Note that A is represented AVX.

This will affect the analysis on fault detection of the SCAM machines, which the output parameter is also %DSC-Flipping.

5. DOE

5.1 DOE

DOE-1: Performance of CPO, SPO and SPV from the beginning of set up towards the end before next set up.

The purpose of this DOE is to measure the performance of DEK and Micron to paste and place consistently onto the pad locations on the substrates.

Data is taken from SCAM03. Product is GCR. However, the measurement is based on production carriers.

In this study, SVS is used to measure CPO, SPO and SPV. This is no different with the practice in production floor.

The consistency of SVS is an important factor to ensure the measurement data is not affected.

From the summary (Table 11), we can conclude that

- SVS is very consistent in measurement on the same sample.
- SCAM machine is not performing consistent over the 6-hour period. This may be explained by the factor of
    - Combination effects of Substrate and Capacitor suppliers.
    - Gap tolerances between substrates and carriers.
    - Machine variability.

However, this is happening in actual environment which may contribute to DSC-Flipping.

6. Conclusions and Findings

6.1 Findings

Through the interview with Module engineer and operators, found:

[1] Most of the DSC-Flipping happening at the pad locations in vertical direction compared to horizontal direction on the substrate. This maybe due to the quality of the incoming substrate as the FCM and DEK are operating well within the specification. But no analysis has been done because the data in Workstream consists of DSCT quantity but without specifying the location of the DSCT occurrence.

[2] The aperture of the stencil will get blocked before the new set up (6 hours interval) to change stencil and new solder paste. This should reduce the solder paste volume towards the end of current cycle. But there is no study on the variability of SPV within the cycle.

[3] Current measurement of CPO, SPO and SPV (using SVS) are on all pad locations of 8 substrates which attached to the golden carrier. The data in Workstream for CPO and SPO are single maximum values. The variability of CPO and SPO across all the pad locations cannot be told, which may cause DSC-Flipping happening at a particular pad location.

[4] The data for CPO and SPO are in maximum values of all pad locations on 12 substrates which are attached to a dummy carrier. Dummy carrier is used to measure the SPO and SPV. However, no correlation study is being done between dummy carriers and production carriers.

[5] The effects of human behavior are important for this study. MSes have individual "styles" to perform CPO, SPO and SPV measurement, such as:

  a. Select good data from SVS, or from different batch.

  b. Ignore the minus value in CPO and SPO.

  c. May not sensitive to data out at particular pad location.

  d. May refer to the wrong SPV data in SVS.

6.2 Conclusions

Target: %DSC-Flipping (67% of DSCT is DSC-Flipping) with respect to 6 primary input parameters: Capacitor Placement Offset (CPO) X and Y, Solder Paste Offset (SPO) X and Y, Solder Paste Volume (SPV) Average and Standard Deviation.

From the data analysis in Section 3:

[1] At the Univariate analysis level, the data for input parameters fell within the specifications.

[2] At the bivariate analysis level, there is no correlationships between %DSC-Flipping and input parameters.

[3] At the multivariate analysis level, 2 methods are used, Partial Least Squares (PLS) and Clustering with PCA using FuzzyARTMAP.

  a. The coefficients of PLS model (except the intercept, C) are less than 0.50, which is unable to predict the %DSC-Flipping.

b. The accuracy of Fuzzy ARTMAP prediction is about 30%, which can be considered that this model cannot predict % DSC-Flipping.

We can conclude that these 6 parameters are not significantly correlated to DSC-Flipping.

However, DOE are being carried out to confirm the conclusions. In this DOE, we can conclude that the SCAM machines are not performing consistent but may still perform within the specifications.

From the data analysis in Section 4, the incoming substrate is the main contributor to the high DSC-Flipping. The %DSC-Flipping is deviated from 0.10 to 0.70%.

From all the data analysis, the incoming substrate and capacitor suppliers are contributing far higher of DSC-Flipping than the SCAM machines.

Thus, if we are to model the Fault Detection System, then the challenge will be on

[1] Quantifying the DSC-Flipping caused by suppliers

[2] Increasing the sampling rate of CPO, SPO and SPV with all sampling must be done within the same time frame and tagged to same lot.

[3] Training the MSes to be more sensitive on entering the data into Workstream database.

[4] On-line measurement data (by pad locations on substrate) at SVS as well as with DSCT data (also by pad locations on substrate).

[5] Standardizing of using production carrier to measure CPO, SPO and SPV which will be more representing the actual environment.

[6] Correlation of DSC-Flipping to these parameters by substrate pad locations. Current data for CPO, SPO and SPV are in single values. The variability of CPO, SPO and SPV across all the pad locations cannot be told, which might be the cause of DSC-Flipping at a particular pad location. The data for DSC-Flipping is in general quantity format. The purpose of is to further study the correlationships of CPO, SPO, SPV to DSC-Flipping by pad locations on the substrate, provided if these data are saved in the format by pad locations.

6.3 Difficulties Faced

[1] Previous work by Chiravong on zooming down to these 6 parameters was deleted. After the interview, the previous data analysis is not by product level and at univariate analysis level only. Thus, his past study cannot be a reference.

[2] Correlation and time-based modeling requires time-matching between target and input parameters. The current sampling rate for CPO – shiftly or every 12 hours, SPO and SPV – every setup or every 6 hours. But the data for %DCS-Flipping is almost every 1 hour.

[3] These sampling rates have also caused the amount of data for analysis reducing. The % data represent the whole batch DSCT data is about 4-7%.

[4] In the data, detected errors in 4.75% data for input parameters are found to have missing decimal points, duplicated data or in reverse order. This may take time to filter the errors and reduce the sample size.

7. Appendix

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Figure 1 Overall Plan of Data Analysis on Primary Parameters

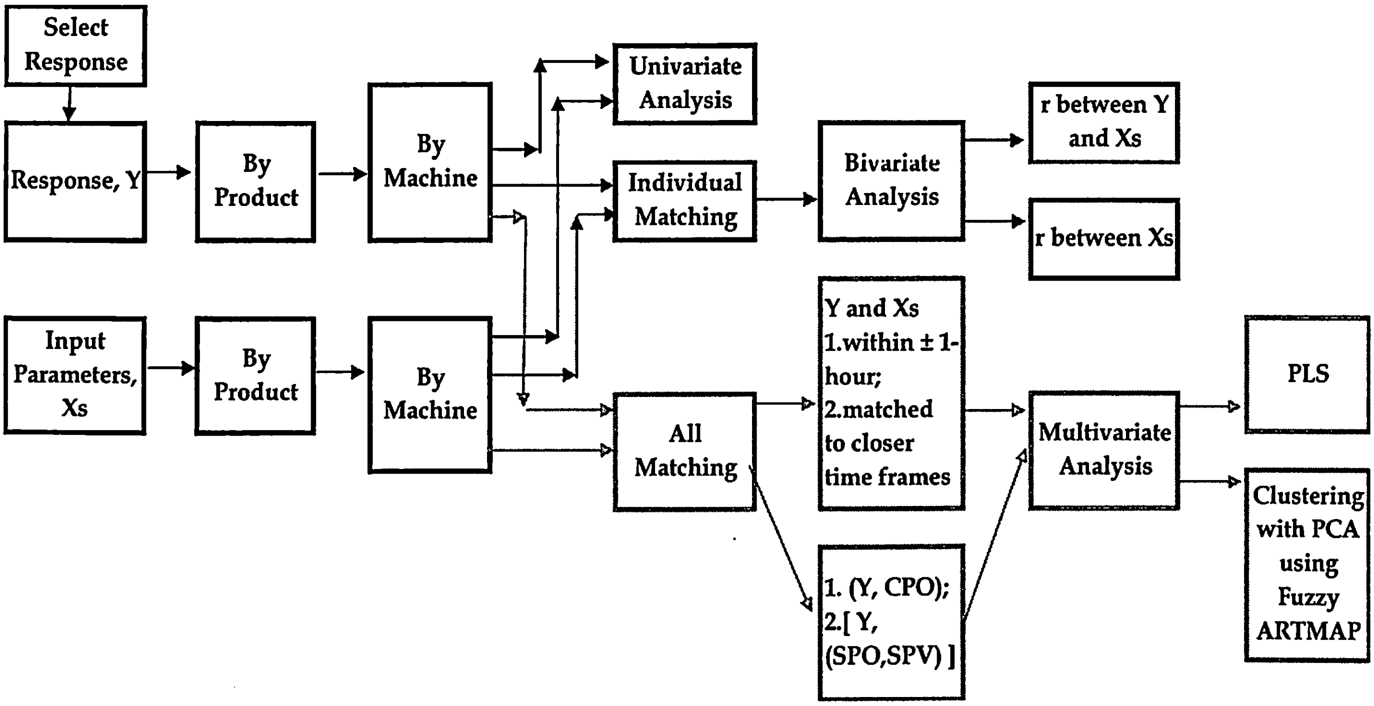


Figure 2 Data Analysis on Output Parameters Selection

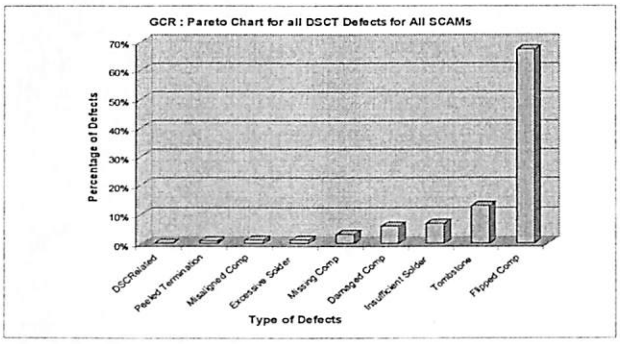


Table 1 Data Analysis on Output Parameters Selection

ENTITY	N	CJ20- Insufficien t Solder	CJ22- Excessive Solder	CJ26- Misaligned Comp	CJ27- Missing Comp	CJ29- Flipped Comp	CJ30- Peeled Terminatio n	CJ31- Damaged Comp	CJ34- Tombston e	CJ35- DSCRelate d	Total CodeQty
FB SCAM 01	927	5.07%	1.33%	0.37%	1.91%	81.89%	0.14%	0.99%	8.31%	0.00%	100.00%
FB SCAM 02	930	7.32%	1.35%	0.18%	5.79%	70.83%	0.00%	1.89%	12.66%	0.00%	100.00%
FB SCAM 03	770	8.60%	8.21%	1.18%	3.24%	60.30%	0.08%	3.47%	14.76%	0.16%	100.00%
FB SCAM 04	757	2.41%	0.94%	3.34%	7.25%	44.16%	0.96%	7.76%	33.19%	0.00%	100.00%
FB SCAM 05	1710	3.45%	0.69%	2.10%	1.93%	64.42%	2.32%	8.78%	16.32%	0.00%	100.00%
FB SCAM 06	1309	5.60%	0.79%	0.49%	4.64%	66.98%	1.07%	8.69%	11.73%	0.01%	100.00%
FB SCAM 07	493	45.56%	0.26%	0.13%	0.65%	50.35%	0.17%	0.52%	2.37%	0.00%	100.00%
FB SCAM 08	3030	5.07%	0.40%	1.86%	2.53%	62.26%	1.62%	9.71%	16.50%	0.04%	100.00%
FB SCAM 09	3623	3.60%	1.04%	0.73%	2.45%	84.36%	0.08%	2.51%	5.20%	0.03%	100.00%
FB SCAM 10	1446	10.40%	6.40%	0.18%	5.09%	71.92%	0.00%	1.67%	4.26%	0.07%	100.00%
All SCAMs	13995	6.88%	1.30%	1.25%	3.28%	67.42%	0.95%	5.99%	12.92%	0.02%	100.00%

Figure 3 Data Analysis on Product Selection

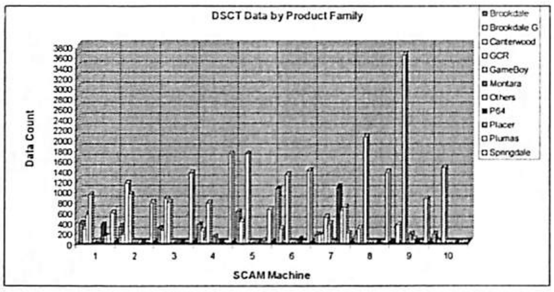


Table 2 Summary of Products distribution at SCAM Machines

By Product,	SCAM											
Data Type	01	02	03	04	05	06	07	08	09	10	Total	%
DSCT (Defect)	3343	3338	3473	3237	3475	4077	3881	3834	5067	1612	35337	100%
Brookdale	380	315	273	346	598	1035	152	162	21	165	3447	9.75%
Brookdale G	365	162	237	229	400	267	144	280	342	0	2326	6.58%
Canterwood	545	1143	841	46	84	3	167	0	1	0	2830	8.01%
GCR	927	930	770	757	1710	1309	493	2030	3623	1446	13995	39.60%
GameBay	7	0	0	4	0	0	366	1	0	0	378	1.07%
Montara	20	0	0	118	0	0	0	0	168	0	306	0.87%
Others	1	0	0	0	0	0	0	0	63	0	64	0.18%
P64	347	13	1	27	20	76	1077	0	1	0	1562	4.42%
Placer	128	4	4	3	31	0	622	1	4	0	797	2.26%
Plumas	156	1	1	0	0	0	681	0	0	0	839	2.37%
Springdale	567	770	1346	1707	632	1387	179	1360	844	1	8792	24.88%

Figure 4 Data Analysis on SCAM Machine Selection

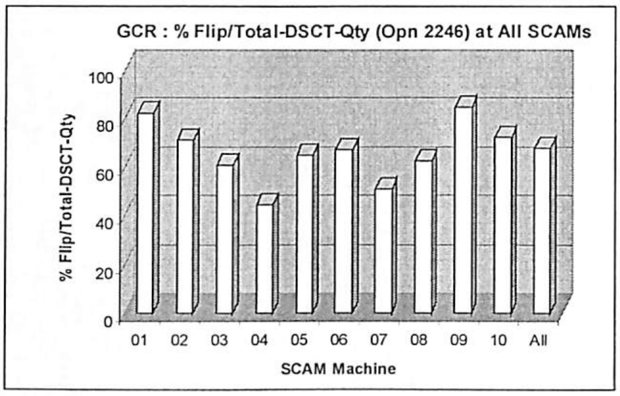


Table 3 Summary of Univariate Analysis on Input Parameters

	CPO-X	Spec : 0 ± 4.5 mils					CPO-Y	Spec : 0 ± 4.5 mils				
	N	Mean	Std Dev	Std Err	Median	Range	N	Mean	Std Dev	Std Err	Median	Range
FB SCAM 01	57	2.035	1.245	0.1650	1.857	4.390	57	1.928	1.412	0.1870	1.829	5.084
FB SCAM 02	51	1.432	1.644	0.2302	1.894	7.500	51	1.681	1.649	0.2310	2.099	5.870
FB SCAM 03	47	0.769	1.850	0.2699	1.000	7.848	47	1.255	1.604	0.2339	1.369	6.681
FB SCAM 04	59	1.589	1.445	0.1881	1.600	7.462	59	1.867	1.392	0.1813	1.968	6.270
FB SCAM 05	96	1.025	2.015	0.2057	1.289	8.807	96	1.238	1.994	0.2035	1.358	8.758
FB SCAM 06	70	1.540	1.214	0.1451	1.596	7.573	70	1.458	1.577	0.1885	1.880	7.721
FB SCAM 07	25	2.043	1.360	0.2719	2.156	6.640	25	1.868	1.359	0.2718	1.900	6.009
FB SCAM 08	78	1.711	1.946	0.2203	1.936	9.808	78	1.752	1.477	0.1672	2.006	7.629
FB SCAM 09	137	1.643	1.503	0.1284	1.950	8.227	137	1.410	1.541	0.1316	1.541	8.486
FB SCAM 10	59	1.389	1.538	0.2002	1.573	8.096	59	1.572	1.550	0.2017	1.700	7.548

							SPO-Y	Spec : 0 ± 8.0 mils				
	N	Mean	Std Dev	Std Err	Median	Range	N	Mean	Std Dev	Std Err	Median	Range
FB SCAM 01	238	1.681	1.316	0.0853	1.526	8.398	238	2.917	1.578	0.1023	2.926	8.987
FB SCAM 02	218	1.819	1.718	0.1164	1.781	11.842	218	2.779	2.038	0.1380	2.787	12.299
FB SCAM 03	217	1.885	1.569	0.1065	1.800	9.872	217	2.969	1.958	0.1329	2.869	12.738
FB SCAM 04	187	1.689	1.551	0.1134	1.621	12.220	187	2.440	1.646	0.1204	2.380	14.547
FB SCAM 05	383	1.369	2.120	0.1083	1.600	13.649	383	2.285	2.531	0.1293	2.407	15.093
FB SCAM 06	229	2.078	1.553	0.1026	2.021	10.797	229	2.955	1.499	0.0991	2.843	8.397
FB SCAM 07	91	1.869	1.602	0.1679	1.810	9.231	91	3.071	1.876	0.1967	2.820	10.613
FB SCAM 08	308	1.940	1.466	0.0835	1.970	11.559	308	2.697	1.524	0.0869	2.500	11.879
FB SCAM 09	576	1.685	1.596	0.0665	1.655	12.035	576	2.355	1.804	0.0752	2.359	12.423
FB SCAM 10	265	1.575	1.566	0.0962	1.523	13.520	265	2.701	1.644	0.1010	2.407	11.165

	SPV-Ave	Spec : 5300 ± 2100 mil3						SPV-Std.	No spec.			
	N	Mean	Std Dev	Std Err	Median	Range	N	Mean	Std Dev	Std Err	Median	Range
FB SCAM 01	241	4836.1	394.1	25.387	4780.4	2004.3	241	282.94	196.53	12.660	258.83	2851.61
FB SCAM 02	218	4739.7	462.0	31.288	4631.0	1980.6	218	313.82	272.03	18.424	288.74	3965.33
FB SCAM 03	217	4560.2	403.8	27.413	4542.7	1800.5	217	260.98	98.33	6.675	245.18	716.18
FB SCAM 04	187	4716.8	450.5	32.942	4664.3	2617.8	187	275.44	99.02	7.241	263.32	686.58
FB SCAM 05	385	4902.1	493.8	25.165	4982.0	3359.7	385	296.02	99.55	5.074	280.41	728.57
FB SCAM 06	228	4795.9	506.3	33.530	4720.6	2293.1	228	305.43	92.53	6.128	290.95	597.14
FB SCAM 07	91	4879.6	494.6	51.850	4887.2	1829.3	91	282.78	102.14	10.707	257.08	445.79
FB SCAM 08	308	4909.1	506.9	28.884	4965.5	3481.1	308	316.64	118.23	6.737	295.85	792.35
FB SCAM 09	576	4790.4	482.1	20.089	4691.7	3033.1	576	284.70	96.93	4.039	278.12	775.75
FB SCAM 10	265	4907.6	493.8	30.334	5007.5	2332.9	265	328.38	301.83	18.541	298.59	4892.74

Table 4 Summary of Bivariate Analysis

Bivariate Analysis : calculation of Correlation Ratio, r

% Flip with	CPO-X	CPO-Y	N	SPO-X	SPO-Y	N	SPV-Ave	SPV-S.D.	N
FB SCAM 01	0.0269	-0.0572	57	0.0887	-0.1179	238	0.0771	0.0620	241
FB SCAM 02	0.0862	-0.1268	51	-0.1433	0.0763	218	0.1027	0.0030	218
FB SCAM 03	-0.0236	0.0520	47	-0.0054	0.0373	217	0.1627	0.0010	217
FB SCAM 04	0.1485	0.1113	59	-0.0059	-0.0397	187	0.0110	0.0001	187
FB SCAM 05	0.0659	-0.1478	96	-0.0339	-0.0316	383	0.0555	0.0537	385
FB SCAM 06	-0.1896	-0.0826	70	-0.0689	0.0486	229	0.1081	0.0084	228
FB SCAM 07	-0.1040	0.1327	25	-0.0742	-0.0196	91	0.3300	-0.0838	91
FB SCAM 08	0.1423	-0.0516	78	-0.0914	-0.0813	308	0.0916	-0.0025	308
FB SCAM 09	0.1391	-0.1694	137	-0.0648	-0.0154	576	0.2330	0.0751	576
FB SCAM 10	-0.0412	-0.1605	59	-0.0588	-0.1090	265	0.2172	-0.0009	265
Overall SCAMs	0.0542	-0.0971	679	-0.0436	-0.0296	2712	0.1191	0.0230	2716

(b) Correlationship ratio, r between the input parameters

	SCAM 01		SCAM 02		SCAM 03		SCAM 04		SCAM 05		SCAM 06		SCAM 07		SCAM 08		SCAM 09		SCAM 10	
	r	N	r	N	r	N	r	N	r	N	r	N	r	N	r	N	r	N	r	N
CPO-X @ CPO-Y	0.4767	57	0.6297	51	0.4970	47	0.3815	59	0.5033	96	0.2685	70	0.6077	25	0.3725	78	0.4330	137	-0.0101	59
CPO-X @ SPO-X	0.2685	56	0.0253	49	0.1978	37	0.6736	48	0.4248	79	0.3521	60	0.4245	22	0.6630	66	0.3207	120	0.5927	48
CPO-X @ SPO-Y	0.3019	56	0.1092	49	-0.2167	37	0.1387	48	0.4260	79	0.0145	60	0.4349	22	0.2089	66	0.4202	120	0.3895	48
CPO-X @ SPV-Ave	0.0605	56	0.1864	49	-0.3421	37	-0.2763	48	-0.2817	79	0.0537	60	-0.4055	22	0.0686	66	-0.0101	120	0.0928	48
CPO-X @ SPO-SD	0.2660	56	-0.0746	49	0.1372	37	0.0501	48	-0.1559	79	-0.0019	60	-0.2688	22	0.0450	66	0.0048	120	0.1638	48
CPO-Y @ CPO-X	0.4767	57	0.6297	51	0.4970	47	0.3815	59	0.5033	96	0.2685	70	0.6077	25	0.3725	78	0.4330	137	-0.0101	59
CPO-Y @ SPO-X	0.2583	56	0.1220	49	-0.1834	37	-0.0387	48	0.4406	79	0.2511	60	0.3086	22	0.1653	66	0.3709	120	0.0840	48
CPO-Y @ SPO-Y	0.2631	56	0.2763	49	-0.0910	37	0.1258	48	0.5620	79	0.0085	60	0.6677	22	-0.1475	66	0.2616	120	0.3538	48
CPO-Y @ SPV-Ave	-0.0986	56	0.0902	49	-0.0950	37	-0.3297	48	-0.1514	79	-0.0042	60	-0.3209	22	-0.1615	66	-0.0894	120	-0.0001	48
CPO-Y @ SPV-SD	0.1003	56	0.1049	49	0.0814	37	-0.0062	48	-0.1907	79	-0.0519	60	-0.1901	22	-0.0275	66	-0.1175	120	-0.0764	48
SPO-X @ CPO-X	0.2685	56	0.0253	49	0.1978	37	0.6736	48	0.4248	79	0.3521	60	0.4245	22	0.6630	66	0.3207	120	0.5927	48
SPO-X @ CPO-Y	0.2583	56	0.1220	49	-0.1834	37	-0.0387	48	0.4406	79	0.2511	60	0.3086	22	0.1653	66	0.3709	120	0.0840	48
SPO-X @ SPO-Y	0.1329	238	0.0651	218	0.3319	217	0.3882	187	0.2286	383	0.1157	229	0.3734	91	0.2712	308	0.3170	576	0.4270	265
SPO-X @ SPV-Ave	-0.0048	238	-0.2442	218	0.0279	217	-0.1394	187	-0.1404	383	0.0064	228	-0.3964	91	0.0163	308	-0.1356	576	-0.2316	265
SPO-X @ SPV-SD	0.1143	238	0.0017	218	-0.1080	217	0.0105	187	-0.0092	383	-0.0442	228	-0.0729	91	-0.0451	308	-0.0556	576	-0.0136	265
SPO-Y @ CPO-X	0.3019	56	0.1092	49	-0.2167	37	0.1387	48	0.4260	79	0.0145	60	0.4349	22	0.2089	66	0.4202	120	0.3895	48
SPO-Y @ CPO-Y	0.2631	56	0.2763	49	-0.0910	37	0.1258	48	0.5620	79	0.0085	60	0.6677	22	-0.1475	66	0.2616	120	0.3538	48
SPO-Y @ SPO-X	0.1329	238	0.0651	218	0.3319	217	0.3882	187	0.2286	383	0.1157	229	0.3734	91	0.2712	308	0.3170	576	0.4270	265
SPO-Y @ SPV-Ave	-0.1237	238	-0.3043	218	0.0491	217	-0.1273	187	-0.0328	383	-0.0832	228	-0.1417	91	0.0835	308	0.0297	576	0.0220	265
SPO-Y @ SPV-SD	0.0830	238	-0.1410	218	-0.1366	217	-0.0316	187	-0.0718	383	0.1396	228	-0.0856	91	0.0652	308	-0.0515	576	0.0547	265
SPV-Ave @ CPO-X	0.0605	56	0.1864	49	-0.3421	37	-0.2763	48	-0.2817	79	0.0537	60	-0.4055	22	0.0686	66	-0.0101	120	0.0928	48
SPV-Ave @ CPO-Y	-0.0986	56	0.0902	49	-0.0950	37	-0.3297	48	-0.1514	79	-0.0042	60	-0.3209	22	-0.1615	66	-0.0894	120	-0.0001	48
SPV-Ave @ SPO-X	-0.0048	238	-0.2442	218	0.0279	217	-0.1394	187	-0.1404	383	0.0064	228	-0.3964	91	0.0163	308	-0.1356	576	-0.2316	265
SPV-Ave @ SPO-Y	-0.1237	238	-0.3043	218	0.0491	217	-0.1273	187	-0.0328	383	-0.0832	228	-0.1417	91	0.0835	308	0.0297	576	0.0220	265
SPV-Ave @ SPO-SD	-0.0839	241	-0.0382	218	0.1930	217	0.0740	187	0.0862	385	0.0794	228	0.1843	91	0.1190	308	0.1396	576	0.1541	265
SPV-SD @ CPO-X	0.2696	56	-0.0746	49	0.1372	37	0.0501	48	-0.1559	79	-0.0019	60	-0.2688	22	0.0450	66	0.0048	120	0.1638	48
SPV-SD @ CPO-Y	0.1003	56	0.1049	49	0.0814	37	-0.0062	48	-0.1907	79	-0.0519	60	-0.1901	22	-0.0275	66	-0.1175	120	-0.0764	48
SPV-SD @ SPO-X	0.1143	238	0.0017	218	-0.1080	217	0.0105	187	-0.0092	383	-0.0442	228	-0.0729	91	-0.0451	308	-0.0556	576	-0.0136	265
SPV-SD @ SPO-Y	0.0830	238	-0.1410	218	-0.1366	217	-0.0316	187	-0.0718	383	0.1396	228	-0.0856	91	0.0652	308	-0.0515	576	0.0547	265
SPV-SD @ SPV-Ave	-0.0839	241	-0.0382	218	0.1930	217	0.0740	187	0.0862	385	0.0794	228	0.1843	91	0.1190	308	0.1396	576	0.1541	265

Table 5 Data Count on 4 Types of Data Pairing

i. Y and Xs are matched within ± 1 hour period

	SCAM										
	01	02	03	04	05	06	07	08	09	10	Total
DSCT	927	930	770	757	1710	1309	493	2030	3623	1446	13995
DSCT with CPO, SPO, SPV	56	49	37	48	79	60	22	66	120	48	585
Sample/Population	6.04%	5.27%	4.81%	6.34%	4.62%	4.58%	4.46%	3.25%	3.31%	3.32%	4.18%

ii. Y and Xs are matched within ± 1 day or closer period

	SCAM										
	01	02	03	04	05	06	07	08	09	10	Total
DSCT	927	930	770	757	1710	1309	493	2030	3623	1446	13995
DSCT with CPO, SPO, SPV	56	49	37	48	79	60	22	66	120	48	585
Sample/Population	6.04%	5.27%	4.81%	6.34%	4.62%	4.58%	4.46%	3.25%	3.31%	3.32%	4.18%

iii. Y and (CPO–X, CPO–Y) are matched

	SCAM										
	01	02	03	04	05	06	07	08	09	10	Total
DSCT	927	930	770	757	1710	1309	493	2030	3623	1446	13995
DSCT with CPO	57	51	47	59	96	70	25	78	137	59	679
Sample/Population	6.15%	5.48%	6.10%	7.79%	5.61%	5.35%	5.07%	3.84%	3.78%	4.08%	4.85%

iv. Y and (SPO–X, SPO–Y, SPV–Ave, SPV–SD) are matched

	SCAM										
	01	02	03	04	05	06	07	08	09	10	Total
DSCT	927	930	770	757	1710	1309	493	2030	3623	1446	13995
DSCT with CPO	238	218	217	187	383	228	91	308	576	265	2711
Sample/Population	25.67%	23.44%	28.18%	24.70%	22.40%	17.42%	18.46%	15.17%	15.90%	18.33%	19.37%

Table 6 PLS Analysis

PARTIAL LEAST SQUARES ANALYSIS
i. Y and Xs are matched within ± 1 hour period
ii. Y and Xs are matched within ± 1 day or closer period
Model Coefficients : Y = aX1+bX2+cX3+dX4+eX5+fX6+C

	SCAM										
	01	02	03	04	05	06	07	08	09	10	All
	% DSC-Flipping										
Intercept, C	-0.8934	1.1437	-2.7492	-0.0859	0.5831	-0.3401	-0.9023	-0.4295	-0.6018	-0.4080	-0.3697
CPO-X, X1: a	-0.0096	0.0573	0.0592	-0.0072	0.0175	-0.0645	-0.0377	0.1092	0.0818	-0.0009	0.0381
CPO-Y, X2: b	-0.0158	-0.0432	-0.0141	0.0073	-0.0709	-0.0088	0.0466	-0.0489	-0.0713	-0.0202	-0.0395
SPO-X, X3: c	0.0294	-0.0868	-0.0363	0.0105	-0.0047	0.0072	0.0059	-0.0519	-0.0280	0.0179	-0.0181
SPO-Y, X4: d	-0.0032	0.0007	0.1056	-0.0002	0.0177	-0.0013	0.0220	-0.0138	0.0110	-0.0134	0.0068
SPV-Ave, X5: e	0.0002	-0.0002	0.0005	0.0000	-0.0001	0.0002	0.0002	0.0002	0.0001	0.0001	0.0001
SPV-SD, X6: f	0.0008	-0.0001	0.0006	-0.0001	0.0007	-0.0003	-0.0009	-0.0006	0.0005	0.0000	0.0001

PARTIAL LEAST SQUARES ANALYSIS
iii. Y and (CPO-X, CPO-Y) are matched
Model Coefficients : Y = aX1+bX2+C

	SCAM										
	01	02	03	04	05	06	07	08	09	10	All
	% DSC-Flipping										
Intercept, C	0.1144	0.1685	0.1147	0.0329	0.2973	0.2973	0.1153	0.3049	0.1682	0.1673	0.1961
CPO-X, X1: a	0.0179	0.0573	-0.0144	0.0099	0.0501	-0.0585	-0.0495	0.0707	0.0695	-0.0059	0.0307
CPO-Y, X2: b	-0.0204	-0.0623	0.0215	0.0053	-0.0653	-0.0085	0.0526	-0.0603	-0.0733	-0.0222	-0.0398

PARTIAL LEAST SQUARES ANALYSIS
iv. Y and (SPO-X, SPO-Y, SPV-Ave, SPV-SD) are matched
Model Coefficients : Y = aX1+bX2+cX3+dX4+C

	SCAM										
	01	02	03	04	05	06	07	08	09	10	All
	% DSC-Flipping										
Intercept, C	-0.2851	-0.3693	-0.3824	0.1651	-0.0937	-0.3414	-0.6295	-0.1500	-0.8838	-0.3054	-0.3770
SPO-X, X3: a	0.0397	-0.0311	-0.0039	0.0067	-0.0057	-0.0272	0.0089	-0.0265	-0.0083	0.0065	-0.0075
SPO-Y, X4: b	-0.0430	0.0256	0.0042	-0.0227	-0.0048	0.0256	-0.0004	-0.0232	-0.0028	-0.0157	-0.0046
SPV-Ave, X5: c	0.0001	0.0001	0.0001	0.0000	0.0001	0.0001	0.0002	0.0001	0.0002	0.0001	0.0001
SPV-SD, X6: d	0.0002	0.0000	-0.0001	0.0000	0.0003	-0.0001	-0.0003	-0.0001	0.0002	0.0000	0.0000

Figure 5 Fuzzy Adaptive Resonance Theory Mapping (Fuzzy ARTMAP)

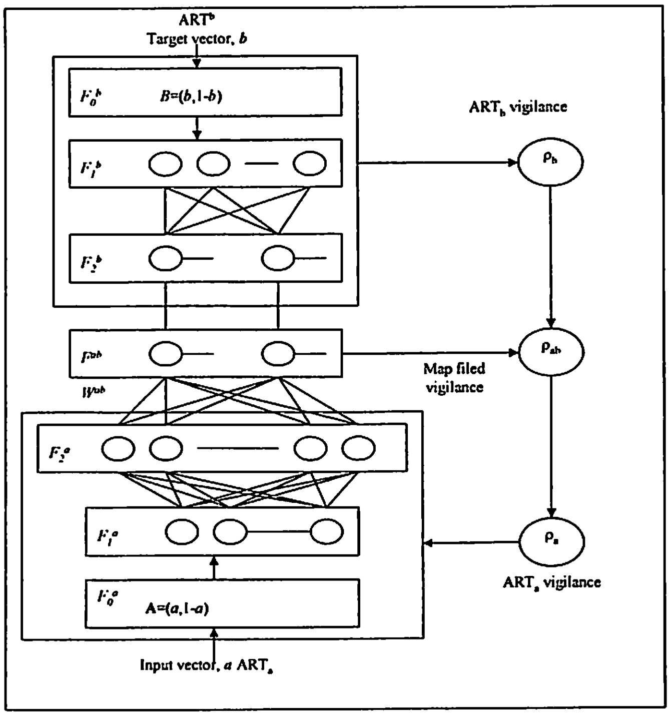


Figure 6 3D Scatter Plot on first 3 Principle Components for
(i) Y and Xs are matched within ± 1 hour period
(ii) Y and Xs are matched within ± 1 day or a closer period

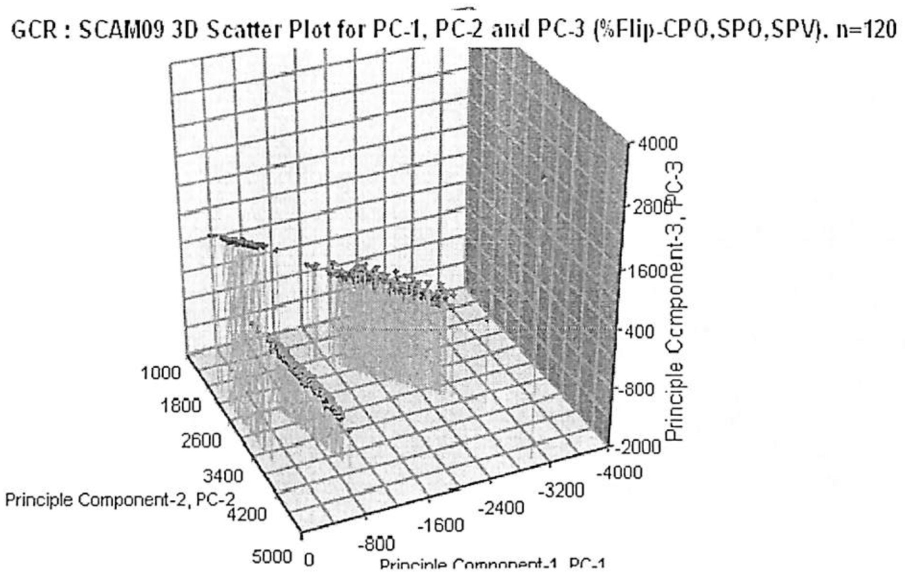


Table 7 Clustering using Fuzzy ARTMAP for
(i) Y and Xs are matched within ± 1 hour period
(ii) Y and Xs are matched within ± 1 day or a closer period

Fuzzy ARTMAP on SCAM 09

8 Classes (%Flip, CPO, SPO, SPV)

Class	Range	# Patterns	Train	Test	Classification result
1	0%	69	48	21	57.14%
2	>0-0.1%	10	6	4	0.00%
3	>0.1-0.2%	12	10	2	0.00%
4	>0.2-0.3%	6	4	2	0.00%
5	>0.3-0.5%	7	5	2	50.00%
6	>0.5-0.7%	4	1	3	33.33%
7	>0.7-0.9%	4	3	1	100.00%
8	>0.9%	8	3	5	20.00%
	Total	120	80	40	**32.56%**
					Mean

5 Classes (%Flip, CPO, SPO, SPV)

Class	Range	# Patterns	Train	Test	Classification result
1	0%	69	48	21	47.62%
2	>0-0.2%	22	16	6	16.67%
3	>0.2-0.5%	13	9	4	50.00%
4	>0.5-0.9%	8	4	4	25.00%
5	>0.9%	8	3	5	0.00%
	Total	120	80	40	**27.86%**
					Mean

*Best result obtained from the adjustment of the FAM network baseline vigilance value.

Figure 7 3D Scatter Plot on first 3 Principle Components for (iii) Y and (CPO–X, CPO–Y) are matched

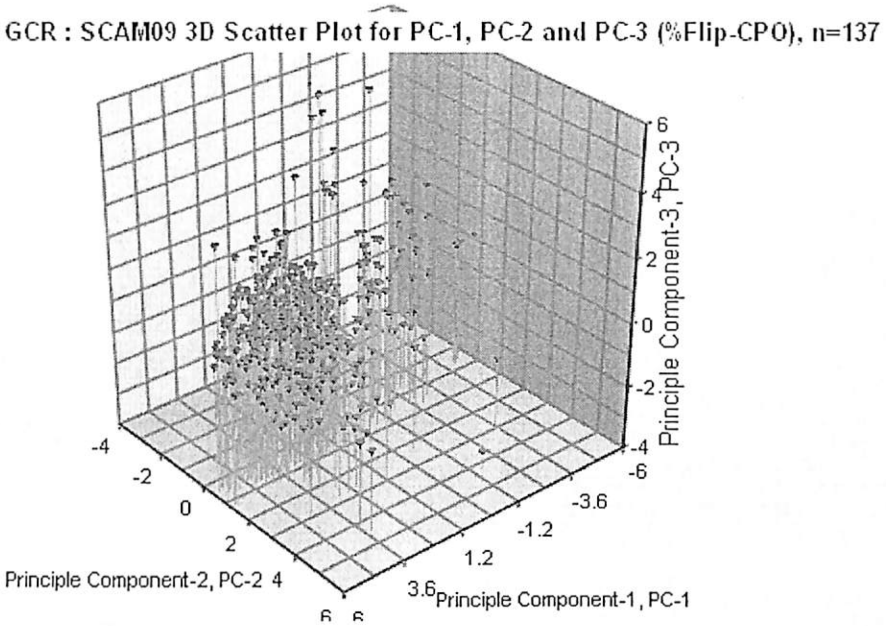


Table 8 Clustering using Fuzzy ARTMAP for (iii) Y and (CPO–X, CPO–Y) are matched

Fuzzy ARTMAP on SCAM 09

4 Classes (%Flip, CPO)						
Class	Range	# Patterns	Train	Test	Classification result (run 2X)	
1	0%	56	28	84	85.71%	82.14%
2	>0-0.2%	18	6	24	0.00%	0.00%
3	>0.2-0.5%	8	5	13	0.00%	20.00%
4	>0.5%	10	6	16	50.00%	33.33%
	Total	92	45	137	**33.93%**	**33.87%**
					Mean	Mean

Figure 8 3D Scatter Plot on first 3 Principle Components for
(iv) Y and (SPO–X, SPO–Y, SPV–Ave, SPV–SD) are matched

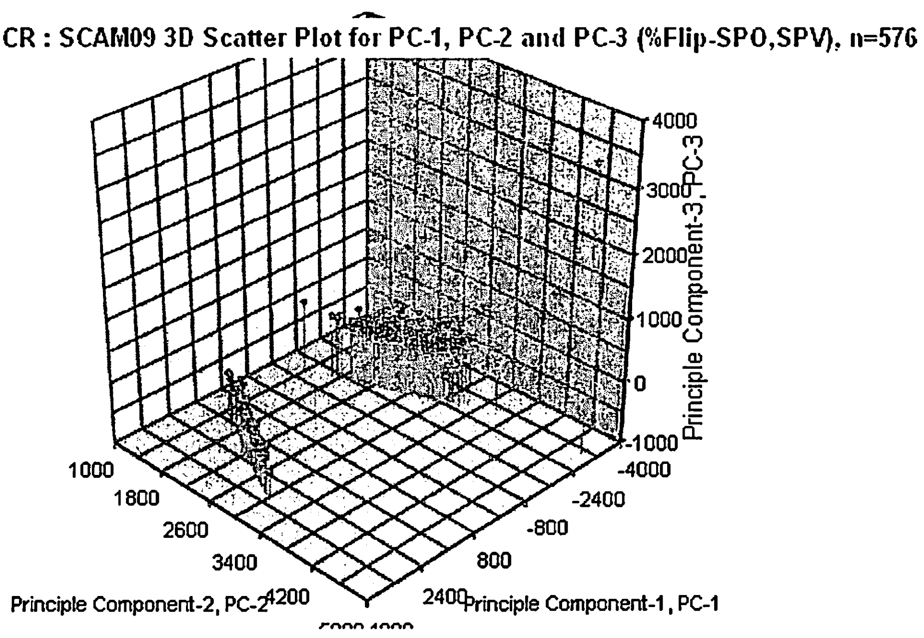


Table 9 Clustering using Fuzzy ARTMAP for
(iv) Y and (SPO–X, SPO–Y, SPV–Ave, SPV–SD) are matched

Fuzzy ARTMAP on SCAM 09

5 Classes (%Flip, SPO, SPV)						
Class	Range	# Patterns	Train	Test	Classification result (run 2X)	
1	0%	342	240	102	93.14%	65.69%
2	>0-0.2%	118	84	34	8.82%	17.65%
3	>0.2-0.5%	59	35	24	0.00%	4.17%
4	>0.5-0.9%	28	14	14	0.00%	0.00%
5	>0.9%	29	13	16	0.00%	12.50%
	Total	576	386	190	**20.39%**	**20.00%**
					Mean	Mean

Figure 9 Overall Plan of Data Analysis on Secondary Parameters

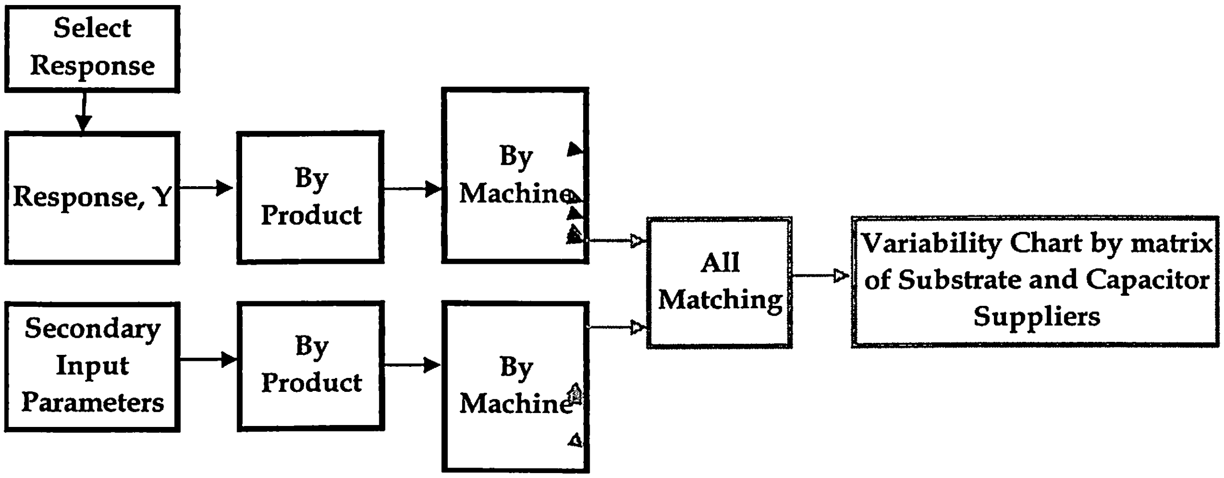


Figure 10 GCR: %DSC-Flipping by Capacitor and Substrate Suppliers (SCAM 01 – SCAM 05)

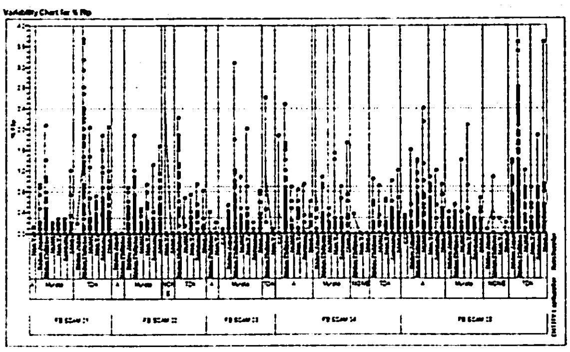


Figure 11 GCR: %DSC-Flipping by Capacitor and Substrate Suppliers (SCAM 06 – SCAM 10)

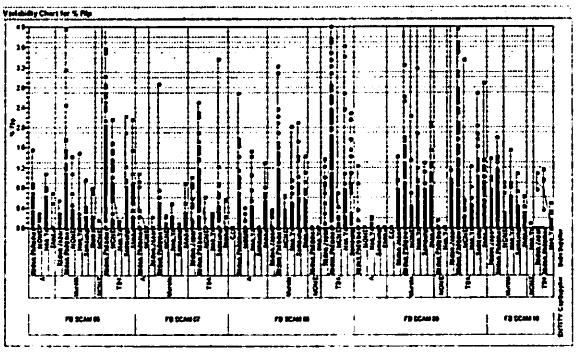
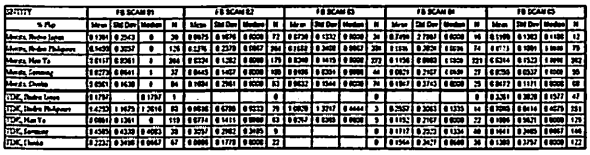
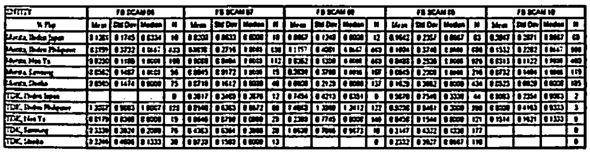


Table 10 Summary of GCR: %DSC-Flipping by SCAM, by matrix of capacitor and substrate suppliers



ENTITY	FB SCAM 01				FB SCAM 02				FB SCAM 03				FB SCAM 04				FB SCAM 05			
% Flip	Mean	Std Dev	Median	N	Mean	Std Dev	Median	N	Mean	Std Dev	Median	N	Mean	Std Dev	Median	N	Mean	Std Dev	Median	N
Murata, Ibiden Japan	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Murata, Ibiden Philippines	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Murata, Nan Ya	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Murata, Samsung	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Murata, Shinko	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
TDK, Ibiden Japan	[illegible]	.	[illegible]	[illegible]	.			[illegible]	.			[illegible]	.			[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
TDK, Ibiden Philippines	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
TDK, Nan Ya	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
TDK, Samsung	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]				[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
TDK, Shinko	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]				[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]



ENTITY	FB SCAM 06				FB SCAM 07				FB SCAM 08				FB SCAM 09				FB SCAM 10			
% Flip	Mean	Std Dev	Median	N	Mean	Std Dev	Median	N	Mean	Std Dev	Median	N	Mean	Std Dev	Median	N	Mean	Std Dev	Median	N
Murata, Ibiden Japan	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Murata, Ibiden Philippines	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Murata, Nan Ya	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Murata, Samsung	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Murata, Shinko	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
TDK, Ibiden Japan				0	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
TDK, Ibiden Philippines	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
TDK, Nan Ya	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
TDK, Samsung	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]				0
TDK, Shinko	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]				0	[illegible]	[illegible]	[illegible]	[illegible]				0

Table 11 Summary of DOE

SCAM Machine is consistent if Repeatedability, R < 30%

	CPO-X	CPO-Y	SPO-X	SPO-Y	SPV
Sample size	108	108	216	216	216
Data with R >30%	77	54	151	179	216
% of data with R>30%	71.30%	50.00%	69.91%	82.87%	100.00%
% of date with R<30% (consistent)	**28.70%**	**50.00%**	**30.09%**	**17.13%**	**0.00%**

SVS is consistent if Repeatedability, R < 30%

	CPO-X	CPO-Y	SPO-X	SPO-Y	SPV
Sample size	108	108	216	216	216
Data with R >30%	7	0	0	0	0
% of R>30%	6.48%	0.00%	0.00%	0.00%	0.00%
% of date with R<30% (consistent)	**93.52%**	**100.00%**	**100.00%**	**100.00%**	**100.00%**

Table 12 Summary of Total Extracted Data

	SCAM										
Data Type	01	02	03	04	05	06	07	08	09	10	Total
DSCT	927	930	770	757	1710	1309	493	2030	3623	1446	13995
SPV	241	218	217	187	385	228	91	308	576	265	2716
SPO	238	218	217	187	383	229	91	308	576	265	2712
CPO	57	51	47	59	96	70	25	78	137	59	679

Figure 12 Summary of Total Extracted Data

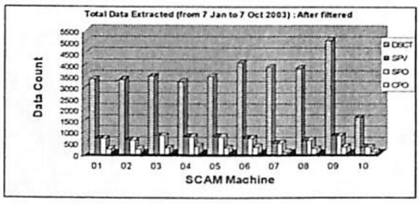


Table 13 Summary of Errors in Extracted Data (Primary Input Parameters)

CPO. SPO. SPV	
Total Data	8775

Data Errors	Count	Deleted
CPO	1	0
SPO	21	5
SPV	6	0

Repeated CPO	30	15
Repeated SPO	359	2
Repeated SPV	323	0

Total errors	417
% errors	4.75%